the Horse Hoeing Husbandry



by Jethro Tull, esq.

Fifth Edition

by Aaron Brachfeld and Mary Choate

2010

Translational assistance from Justin Walker

THE

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It is said that mine is the first book of Agriculture that has happened to be pirated...
—Jethro Tull, supplement of 1750

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Virgil's Georgic very pleasant, innocent, amusing, diverting poetry, captivating to reasoning minds. However, the Georgic was intended to praise a Roman government based on the perpetual slavery of the bravest people of the world, and Virgil himself was an enemy to liberty. In any case, he was one of the best of poets, and the worst of husbandmen 205

OF TURNIPS, RYEGRASS, ANIMAL PASTURE, GRAZING, FRUITS AND VEGETABLES 206

TURNIPS 206

Turnips only recently domesticated in England 206

All lands, when made fine by tillage, will produce turnips, but not equally as well: turnips are thirsty plants that require heat: sandy and gravelly lands are the best, chalky grounds are the worst 206

If well tilled, dews provide enough moisture for germination 206

Hand hoeing is insufficient, especially when hoers are deceitful 207

Plant turnips on ridges with one row per bed and with six feet between rows and yield should be double that of turnips planted three feet apart on the level – however, level-planting is better for dryer, hotter climates 207

Plant on the Ridges 207

Plant turnips in halves: half four inches deep, and the other half one inch deep to guard against uncertain weather: if the weather is dry, the deeper ones will come up, if wet, the shallower ones will – planting polycultures with cold, hot, dry and wet adapted plants similarly reduces risks of a variable climate 207

Mix old and new seed at two different depths for four sprouting times: older seeds come up later than newer seeds. This reduces the risks of crop loss due to herbivores by allowing predators to respond to the herbivore population should it be abnormally large 208

Covering the turnips with a little soil protects them against insect pests without significantly damaging them; replanting if destroyed also will result in a crop with little additional expense. Rolling the ridges compresses it and reduces the ability of insects to lay eggs in the ground, and while damaging to the crop, is remedied by hoeing the aisles 208

When 72 inches are allowed between rows, aisles may be left higher than the beds 208

Weed and thin the turnips early 209

Plant thinly: 3-4 ounces of seed per acre are typically required. An exception is when raising sprouts or baby greens: planting densely retards growth, stunts them and otherwise makes a more desirable product that is easier to harvest 209

Planting time varies by location 209

Fewer rows per bed make for larger turnips 210

Deep hoeing improves the effects of rain water 210

Intercropping wheat with turnips by planting in the aisles, tilling the turnip beds upon harvest 210

Thin out lesser turnips so that turnips are about 12 inches apart at closest: they will sometimes grow to be bigger than that 210

It is better to hoe aisles alternately and frequently than simultaneously and infrequently 211

Hoeing improves drought tolerance 211

Expect yields of 12 pounds per turnip for the Great Turnip variety, with potential yields exceeding 19 pounds 211

If harvesting turnips too late in the spring, the next crop cannot be planted in time and the opportunity lost is greater than the income gained by the turnips 212

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How to feed turnips to sheep and other animals IV: harvest the turnips from the field and cart them to the animals, this will allow ground to be used as efficiently as the turnips by permitting replanting and reduce disease in the sheep 214
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The general success of the Tullian feedlot, and the strategy of using cheap rangeland for the growing of animal feed crops: possibilities of continuing the strategy today. Penning and feeding cattle is more profitable than grazing them, even on rangeland that does not yield hay or other animal feeds well – discussion on hay production profitability, wheat straw as animal feed and market dynamics for animal feed in beef production 223

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Hay and cattle operations (and the trucking operations that unite them) can be viewed as a single unified operation of growing hay and feeding cattle, with the division of the profits from the sale of the beef divided between the rancher, the farmer and the trucker who transports both hay and cattle, favoring the farmer significantly, encouraging the farmer to relocate operations close to the rancher to earn a larger share of the trucker's income 228

Farmers choose the best land to farm on, not necessarily those which are closest to the demand of ranchers (which is typically poorer land), however, with Tullian agriculture and animal-power, so-called marginal lands are well suited for agriculture and the farmer who foregoes the tractor and undertakes traditional Tullian agriculture stands to earn more per acre 229

FRUIT AND VEGETABLE FARMING 233

Turnips are a kind of vegetable, and vegetable and fruit farming for human consumption was not popular in Tull's time, such foods were typically imported from the Continent until just recently. However, we believe that such notes on the production of turnips and other vegetables would naturally be annexed to the chapter to turnips and have included them here. –A.B. & M.C. 233

Fruit and vegetable production and consumption was not common in England until after Henry VIII (about 1547), this shaped modern eating habits against fruits and vegetables; also, basic biological instincts discourage people from seeking the fruits and vegetables necessary to their health 233

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OF SANFOIN 315

Sanfoin is also called French Grass because it originated in France, Everlasting Grass because it can last upwards of 40 years, yet it is not a grass (strictly speaking). It is also called Sain Foin, Sanum Faenum, Sanctum Faenum (Holy Hay) because it is more wholesome than other hay whether dry or green. Sanfoin provides excellent bee pasture, as well. 315
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2. All plants rob other plants within their reach of food 377

3. Soil which is proper to one kind of vegetable once is, in respect of the sort of food it gives, proper to it always 377

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In choosing to import seed rather than save last year's seed for next year's planting, the farmer is choosing plants which are adapted to different climates than that in which the farm is located: such seeds, while of the same genotype, are of a different phenotype (having the same genes, but presenting them differently) because a parent generation will effect which genes are activated and deactivated in their progeny 392

Climate may differ even from one side of a mountain to another 392

Climate sometimes varies even within a single field 392

Climate effects the characteristics of plants: in example, flax imported from Holland produces as fine of flax when planted in England only the year of the importation, its progeny adapts to English conditions and degenerates within 2 or 3 generations 393

Similar effects of climate can be observed in all species, especially wheat, silk worms, barley, etc.; the value of buying from breeder farms 393

Seeds and grains are to plants like eggs are to birds, and some disease can be transmitted between mother and seed or grain 395

Weeds require no change of individuals 395

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Ridges can reduce water on land by facilitating run-off to rivers, or in desert lands, retard water run-off, in desert lands, ridges reduce wind erosion 398

The more water there is in a soil, the cooler it will be 398

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Alternative method of draining such a hill: French drainage (trenches filled with stones and covered with soil) must be laid across the descent of the hill and is destroyed over time by tillage 399

It is better to plow drainage ridges across the hill, like French drainage: these tiny ditches bring the water to the edge of the field where the parting furrows lie open and drain down the hill; it is best to make the bottom of these furrows as deep or deeper than the surface of the clay understratum 399
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Another objection: hills, when brought to terraces, will not have the same surface area as had the land been level entirely. Answer: that fewer plants may stand on an acre does not mean that less production will be yielded; and because they eat soil, and hills have more soil, it is just as likely that hills can be more productive than flat lands; and if planted in rows that follow the curve of the hill, no loss in row feet is observed 403
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dig deeper and break ground finely 813

I suppose I need not give any caution about muzzling the oxen because they will eat the plants as soon as they come an inch above the ground, and that will show the necessity of it. But there is no occasion to muzzle the horses until the plants are grown as high as their noses when reined up.

—Jethro Tull, suppliment of 1750

PREFACES

Letters to Tull upon the publication of his work

London, February 8, 1732.
My Dear Sir,

****** showed me your letter to him of the 3rd of this month. I am extremely sorry to observe from it that you are under great discouragement at present. I hope you'll believe I am very sincere when I tell you I am much interested in your preservation from the happiness I have of a personal acquaintance with you as well as from the concern I think the public has in a person who has labored so successfully for its service. I would fain hope that the apprehensions you had from your spitting of blood are long before this time removed by its having ceased. If that's the case, I must conjure you for the sake of your own glory, and for that of your country's benefit to apply heartily, and without of loss of time, to the publishing of your work. If you cannot get an A— from Oxon speedily, pray let ***** send you out one from hence. I am persuaded the subscription money will go far towards printing your book, but if any thing should be wanting you may be assured that your friends here will contribute towards having a work so beneficial communicated to the country and in a way that the profit arising from the sale of your books shall return to yourself. The hardship that has happened to you from the reprinting your book at Dublin might easily have been prevented if we had forseen that the thing was to have happened. But now that we are aware of the inconvenience, you may depend upon it, your friends will either get a stop put to the printing from hence, or by the means of the authority of my Lord Lieutenant of Ireland.*

*I am ever, with great esteem, My dear Sir, yours, ******

September 19, 1733
Sir,
*I have the pleasure to be studying your book. I have three of them, which Mr. ***** shall account with you for; but I think there is a great deal due (besides the price) for so great a treasure. My own Thanks, as well as those of all England, will be yet too little for what much better Judges than myself esteem as the finest piece of natural philosophy ever was wrote, besides the addition of your own experience and most admirable invention. The more I read, the more I am convinced that there is no other way of raising wheat to any advantage (or without loss) but by the drill and the hoe plow. I am now strongly resolved to do what I have been too careless of.*

*Dear Sir, Your ******

THE FIRST EDITION BY JETHRO TULL

PREFACE

About the author: I am a farmer, not a scholar

Writing and plowing are two different talents, and he that writes well must have spent in study that time which is necessary to be spent in the fields by him who would master the art of cultivating them: to write effectually of plowing, one must not be qualified to write learnedly!

Scarcely any subject has had more of the ornament of learning bestowed upon it than agriculture has by writers both ancient and modern. But a late great man, who was the Cicero of the age, having perused all their books of husbandry ordered them – not withstanding their eloquence – to be carried upon a hand barrow out of his study and thrown into the fire lest others should lose their time in reading them as he had done. He declared that he could not – for all his life! – guess what those authors would be at for they treated of an art wherein they formed no manner of principles.

Now, if these learned volumes that were so eloquently written and so little to the purpose have done nothing but mischief, it is time that something should be written different from them in both respects.

How far I am capable of performing such a task in one of these respects this essay will show, but what I have done different from them in the other of the two respects cannot be fairly judged before the whole appears. And, because some circumstances make it uncertain whether ever it may all appear publicly, I will give an account of it now.

Purpose: to increase the profit of the land through the introduction of vineyard techniques to field crops

The design of the whole is to increase the profit of the land by introducing a sort of vineyard culture into the fields. It is founded upon principles which, if they are true (for I can only say that I think them so) they must be (as all truth is) eternal, and yet are not extant in any author's work that I can find or hear of.

These principles I have comprised under the following heads, or chapters:[1]

1. Of Roots
2. Of Leaves
3. Of the Food of Plants
4. Of the Pasture of Plants
5. Of Manure
6. Of Tillage
7. Of Hoeing
8. Of Weeds
9. Remarks on the Bad Husbandry that is so Finely Expressed in Virgil's First Georgic
10. Of Drilling and Managing Turnips and such Like Crops for the Feeding of Cattle
11. Of Drilling and Hoeing Wheat
12. Of Smuttiness of Wheat
13. Of the Blight of Wheat
14. Of Drilling and Managing Sanfoin and every Thing that May Concern It
15. Of Alfalfa

And these

1. Of Crop Rotation
2. Of Change of Seed
3. Of Ridges
4. Of Plows
5. Of Some Differences Between the Old and the New Husbandry

The first 9 Chapters consist of experiments, observations and arguments to prove those principles in theory which seem to solve all the phenomena of vegetation necessary to be known in agriculture.

The next 6 Chapters show how these principles are to be put into practice, for however plausible they might appear in their speculative view, I should have rejected them on account of their novelty if I had not seen the truth of them fully demonstrated in the field.

Most of what is said in the first of these 5 Chapters (here presented to the reader) concerning the Change of Species might have been inferred from some of the arguments in the Chapter of Weeds, but because Dr. Woodward's arguments seem to have been sufficient to draw after him Mr. Bradley, Mr. Mortimer and I know not how many other writers into his opinion, I thought it necessary to be more full in arguments against it. It is the ill consequence of the Old Husbandry that encourages the sloth of farmers to neglect the due tillage of their land for killing weeds and would render useless that part of our New Husbandry that destroys all weeds. Besides, another great advantage his opinion would take from us (if we believe that every species takes only a specific nourishment that is proper to that species alone) is that when we have found a species of vegetables that suits the degrees of heat and moisture (which may be called "climate") of a soil, and whose

[1] We have preserved Jethro Tull's chapter organization presented in the Second Edition. – A.B. & M.C.

produce also suits our markets, we must – after one or two crops – change it for a different species which suits neither the soil or the market so well.

Method is easily tested and proven and the farmer is encouraged to test and prove it

Some arguments are very light but weigh heavily with some people than others of greater weight, and a common farmer will reject a false opinion sooner when they are shown it to be ridiculous than for the strength of arguments of reason that can be brought against it. Therefore I must prevent an objection that may perhaps be brought against me by saying that all the species of plants that have been yet tried by my hoeing husbandry grow every year better without rotation.

My objectors may allege that my aisles, kept from being exhausted, present every year a change of soil but, in truth, they were planted in narrower intervals than I use at present and the plants sent their roots through the aisles. Yet when they had more pasture raised by the hoe and were robbed of it by weeds, there still remained sufficient pasture from another crop of the same species to succeed in the next year. I have at this time, in such aisles, a 5th annual successive crop of wheat – without intermitting any year and without assistance of dung or manure – that is stronger than any one of the four preceding crops, and stronger still than any wheat in all the neighborhood.

Novel to conventional understanding, no acknowledgements made

A late author advises that Dr. Woodward's *Of Vegetation* be inserted into every treatise of agriculture and I must advise the reader to peruse him at large because I have, by mistake, omitted to insert some part which I have answered and because another material part which I have answered and inserted is omitted in Mr. Lowthrop's *Abridgment*.

Changing seed but not the species of our crop relates particularly to the changing of seed wheat. I hope it is fully treated of in the Chapter on Smuttiness.

I have had a wet spewy hill of my own made dry by only plowing the ridges cross its descent instead of plowing them up and down, but whether a hill is worth more than the ground it stands on does not concern me, therefore I would have said nothing about it had not Mr. Bradley's arguments thereupon had not seemed to interfere with part of my theory.

The seed drill was inspired by a need to reduce labor requirements and the mechanics of a Church Organ

Under the title of plows I intended to have placed the descriptions of all my particular instruments of agriculture – especially my drill, whereupon this husbandry depends, and it is impracticable without it. I should not trouble the reader with an account how accidentally it was discovered were it not to show that the knowledge of a thing which seems despicable or impertinent may unexpectedly become useful at one time or another.

When I was young my diversion was music, though I also had the curiosity to acquaint myself thoroughly with the fabrication of every part of the organ. But, I did so little thinking that I should ever take from thence the first rudiments of a drill or that I would ever have the occasion of such a machine or even to practice agriculture. It was accident, not choice, that made me a farmer (or rather many accidents which could not then possibly be foreseen).

It was my chance afterwards to have a large farm in Hand which I could not well dispose of and, it being about the time when plow servants first began to exalt their dominion over their masters so that a Gentleman farmer was allowed to make but little profit of his arable lands (and almost all of mine being of that sort) I resolved to plant my whole farm with sanfoin. But the seed was scare and dear, and most of what was available was little good. I found that it would be difficult to procure a sufficient quantity to sow at 7 bushels to the acre (which it was usually sown).

So I began to examine whether so great a quantity of seed was absolutely necessary and whether the greatest part of the seed sown did not commonly miscarry – either by its badness or from being buried too deep or else lying on the ground uncovered. And I observed in several fields of sanfoin (sown with 7 bushels to the acre) that in those parts of them that produced the best crop there were (as I counted) but one plant for each square foot of surface. And yet the number of seeds in 7 bushels per acre amounts to 140 per square foot!

I then observed that in other parts of the same fields where less off the seeds miscarried and the sanfoin was thicker, the crop was less. Then, after I had learned perfectly how to distinguish good seeds from bad and had – from many trials – found that few seeds (even the best) would succeed if not covered to the correct depth (especially in strong land) and had also found the reason of this necessity, I employed people to make channels and sow a very small proportion of seed therein and cover it exactly.

This way succeeded to my desire and it was in seed and labor but a 1/4 the expense of the common way – and the ground was better planted!

The 10 acres I experimented upon did so well that I had no doubt that 1,000 acres would succeed as well. But when I attempted it the next year I found that these people had conspired to disappoint me and planned to never plant a row tolerably well again. They were jealous that if a great quantity of land should be taken from the plow it would prove a diminution of their power and so I was forced to dismiss my laborers and resolved to quite my scheme unless I could contrive an engine to plant the sanfoin more faithfully than such hands could do.

To that purpose I examined and compared all the mechanical ideas that ever had entered my imagination and at last pitched upon a groove, tongue and spring in the soundboard of an organ. Altering these just a little (and some parts from two other instruments as foreign to the field as the organ is added to them) I composed my machine: I named it a "drill" because when farmers sow their beans and peas into channels or furrows by hand they call the action drilling.

My drill planted that farm better than hands could have done and many more hundreds of acres than the hands could have done besides. And 30 years' experience shows that sanfoin thus planted brings better crops that last longer than sown sanfoin.

This drill has also been used almost as long in planting most sorts of corn for hand hoeing and these last 9 years for horse hoeing.

The four coultered (disk) plow and two wheeled plow invented to be useful in old and new husbandries

The hoe plow was also intended to have been described here – it plows as deep and as well as a common plow and differs but a little from it. But this hoe plow has shafts (or thills) instead of wheels and is contrived so that the cattle that draw it will not tread upon the rows when they plow between them.

The four coultered plow is very useful in the old husbandry and in preparing land for this. I was writing directions on how to make it, but when I found that they would be imperfect without illustrations, I laid them by because I did not think it reasonable to be at such an expense on the account that it is only an improvement to a common two-wheeled plow before I had illustrated the drill, which is an original invention of my own.

However, I have taught 3 plow-wrights to make these four coultered plows and though two of them are dead, the survivor is so perfect a workman that of all he has made, not one has failed to perform well (at least, so I am informed).

And, I believe, a good workman who can make a two wheeled plow to go well with one coulter (which few can) may make this one, having another beside him for an example.

Oxen more affordable than horses due to reduced risk of theft

The most affordable tillage is (I suppose) done by oxen, especially since servants have the liberty of robbing barns to give horses too much corn with the intent of killing them (when they have a mind to punish their master's disobedience).

Oxen may be kept on almost any enclosed farm at very small expense. By the my new methods of agriculture, we may raise as good cabbages and carrots in the field as grow in the garden and – with these and turnips – oxen will live all the year without the help of pasture or hay.

It may seem absurd that I call my husbandry by the name of "Horse Hoeing" when it is performed by oxen! But the truth is that it had acquired that name before I learned that oxen were capable of performing it.

Agriculture in aisles, rows and beds is advantageous, simple to undertake and requires equipment affordable to manufacture or buy

Those who think the fields can have no advantage from being planted in rows would do very well to try it if they can persuade the gardeners to set their plants irregularly and sow all their seeds at random!

For my part, if I know of any substantial objection against this husbandry in of itself, I would not conceal it. I know there are many objections against its being practiced by those who do not understand it.

I have never advised those who do not understand the method to attempt it. Rather, I have dissuaded them – as much as I could – against drilling great quantities of wheat before their own practice in small pieces have made them perfect in this method by teaching the principles which are necessary to direct them in it. As wheat is generally the most profitable crop – so it requires the greatest circumspection in the management.

For other crops the same directions would be given. So many various circumstances usually occur in the long time that wheat ought to live that, I think, one can give no bare directions in them all before they happen, but what may endanger the deceiving of the person they are intended to serve unless the principles themselves accompany those directions.

Some, perhaps, may suppose that these principles are very numerous and prolix because they cannot be written as easily as directions which result from them. But, in truth, they are not so – for a few lines would contain them all if they had received the approbation of proper judges. In the mean

time, they are either so new or paradoxical that I cannot – without reluctance – write any of them separately from the arguments I bring to support them. And no man can judge so impartially in his own cause or of his own arguments as another who is unconcerned may, but when they are published, every farmer that approves of them may make his own judgment and then, whether he uses or abuses them, he cannot (I hope!) justly blame me for his conduct.

It is objected that this husbandry cannot be commonly employed by reason of the instruments on which it depends. It is said that they are heavy and troublesome to carry far distances and very few workmen know how to make them, and therefore we must not only submit to such price as their conscience will set upon them, but also dispense with their mistakes if they are not fatal ones, or less the drill alone and teach workmen. For, it is said, that no other without the rules can make one good drill by another – though everyone is positive he can. But when he has done his utmost to imitate or (as he thinks) to improve it, it is (in all that I can hear of by such workmen) good for nothing.

This objection is adequately responded to by the illustrations here provided and explained by a short treatise describing the manner of making and using the drill. This I have done before now in order to prevent the deceit of pretenders, but considering how imperfectly most engines are described, I resolved to describe the drill effectively or not at all. For which purpose, a more than ordinary number of cuts are necessary to show every part in all its views and drawing and engraving being very expensive – especially to one who lives so far from London – I found the end of my labor would be to take off an expense from others and to lay a greater upon myself and therefore I desisted from finishing what I had begun, deferring it to some better opportunity.

As for the expense of the instrument, a drill being made in box wood instead of brass may be had for a very small price.

Using aisles, rows and beds requires training and practice

As to the objection[2] concerning the wickedness of servants and laborers in husbandry, of hedge breakers and of takers away of our corn (and other products of our land and labor) at harvest, though it is a wickedness never heard of in any other age or country, it ought not to be objected against my husbandry in particular unless it affected it alone.

What I most apprehend is the rashness of those who will enter upon the practice of drilling wheat before they are sufficiently informed concerning it: they cannot avoid being liable to make many errors.

They may drill it among the couch grass or other perennial weeds that cannot be extracted from the rows of wheat (though they may easily be taken from the rows of turnips). They may drill their wheat on land that is full fraught with seeds of poppies and other annual seeds that may be pulled out of the rows and yet they may neglect to do it and suffer them to ripen (which will occasion the loss of two wheat crops by saving the expense of saving 2 Shillings per acre – which is, in farmer's phrase, no better than losing a sheep for wanting a half penny worth of tar). They may drill their wheat at unseasonable times (such as the frost of winter) and then the rooks will have a fair chance to come in for the greatest part of it and the rest will be in danger of dying with the cold.

[2] Tull indirectly refers to the difficulty of undertaking this husbandry by hand and the skill required of any employee that might undertake it for their employer. –A.B. & M.C.

They may drill a greater quantity than they have than they have strength of cattle to manage and then the plowing of the last furrows of the ridges may not be finished until the spring of the year (which is the season wherein the second hoeing ought to be performed by throwing up to the rows the fine soil mellowed by the frost, having laid open all the winter for that purpose).

They may plant bad seed that will not grow, or that is foul and infected with smut. They may plant the wrong sort of wheat – for not every sort does equally suit every soil or even equally suit this husbandry. The sort that I have found to fit every soil that I have tried it on and makes the best hoed crop is the white cone wheat – it is a white bearded wheat whose straw has a pith like a rush. Also the red lammas wheat with white ears (though it is a little dwarfish, it makes a good crop). The grey cone does well also, but the common red strawed and white strawed lammas wheat are difficult to manage – especially on such land is usually subject to the blight of insects. For which reason I cannot advise a beginner to venture on those sorts.

There is another sort which I conjecture would exceed all other sorts in this husbandry because it is the largest of all and requires the most nourishment. It makes a prodigious crop in a garden, but is much less when sown in the field in the common manner. Its ears in the garden were the biggest I ever saw, having many smaller ears all round the bottoms of the great ones. But when sown in the field, the ears are in general no bigger than those of other wheat. It is bearded but not grey. I have seen none of it these many years and can only recommend it to be tried by such drillers who know where to get it.

Expense of tillage and hoeing less than conventional costs

I would gladly save my fellow drillers the expense of weeding their rows of wheat before the land has been cleaned by fallow or otherwise. But this cannot be done while any spurious seeds remain in it. Unless weeds had such an antipathy to the drill as the ancients fancied their alfalfa had to iron so that they might refuse to grow because the drill passed over them. But since it is so far otherwise that the weeds will not only come up in the rows but also, if not taken out, will receive as much vigor from the hoeing as the will, therefore when land is very subject to weeds (that is to say, full of their seeds and roots), the cheapest way of cleaning it is to plant thereon two successive crops of turnips (or such plants) among which the horse hoe and hand hoe may go near to extirpate the whole race of weeds, both annual and perennial. In the second year's crop of turnips, the wheat may be drilled in the intervals before the turnips are taken off. This I have done, but then they ought to be spent early, for if they should stand all the winter, they would injure the wheat.

Wide aisles are as necessary and useful as they are outrageous

But alas! Where there is not faith enough to drill rows of turnips so wide as 3 feet apart, how will there be faith to plant rows 6 feet apart? But it is found that a competent number of turnips (suppose 36, 48 or 60) drilled on a perch[3] of ground in rows 6 feet apart may be brought to greater perfection than the same number can be brought on the same perch drilled in rows 3 feet apart. The wide rows will be but half the expense of the narrow and must be ill managed indeed if they do not amount to the quantity of 4 commonly sowed crops.

[3] One perch is equivalent to a rod, which has the (approximate) modern length of sixteen and one-half feet. —A.B. & M.C.

Many are prejudiced against wide intervals, but when that matter is fully debated, they will be found to have been much in the wrong. I call a narrow interval in wheat 3 foot 8 inches, and a wide one 4 foot 8 inches. This added soil may be well pulverized, and when it is so, 1 foot will have as much food in it for the plants as 10 feet of the same soil unpulverized.

2 furrows hoe the wide and 1 furrow hoes the narrow: all the difference of expense is the rent of this added foot. Now, an acre being 66 feet wide and 660 feet long, the quantity of added soil is 660 square feet which, at the rate of 11 Shillings per acre rent amounts to 2 Pence and no more. I can't think a treble row to be well managed unless it produces 2 bushels of wheat which, at 5 Shillings per bushel, is worth 10 Shillings. But an ignorant farmer, who is no used to this way of reckoning, when he sees the wide interval in the winter or spring, fancies there might be another row in the middle of it as good as that row. And from that computes the difference of the wide and narrow rows at 10 Shillings, while it is actually only 2 Pence.

When the driller desires to know exactly the quantity of a wheat crop, I advise them to cut a row or some certain part thereof before the reaper begins and see it rubbed or threshed out immediately. From this, the driller may calculate their entire crop, for though the necessary waste is less in this than in other wheat, the waste may be by accident become very uncertain: when the ears are very large and a great company of leasers may (especially when the price of wheat is dear) leave behind them less than the owner's usual share...or perhaps the thresher may throw half out of the barn with the straw to increase their wages (if they thresh by the quarter) or to save their labor (if they thresh by the day).

This is an unfinished work, rushed to press by urgency

I wish I could provide ample directions here in every point of management with an account of the whole process of my practice of this husbandry, but that cannot be expected or done out of the proper places. It is certain that what I now offer must be imperfect without the other arts, but I could take nothing else from there without leaving the remainder imperfect.

The reason for my publication of my papers is that I accidentally heard that drills are being made and sent a great way to strangers who are going into this practice without any experience or knowledge of it. I could think of no better way at present to serve them and others who may do the same than by giving them these cautions and assuring them that, in my opinion, if by any whatever mismanagement they fail of success, the fault will must not be imputed to the husbandry itself. For if, despite their mismanagement they should succeed, it is an argument against the truth of the principles whereon the husbandry is founded and that it may not be thus unjustly disparaged.

I do not wish the well-wishers to it be injured by their own rashness, on which account I hope the reader will pardon the oversights I have may made and also some which seem such until further explained.

Manure entirely unnecessary

I need not say writing is none of my business, but I hope the farmer will not regard the roughness of the style because he knows that a plow will never go the better for being polished than besmeared with dung. Yet I must confess that I have much less aversion to dung in the field than I have to the expense of buying and carrying it to there, and I don't doubt but that many farmers will

hate that as much as I do when they are convinced by their own experience that they can go on very well without it.

And if hopes of profit have so much influence on their inclinations as to put them upon making trials, I wish them success.

THE SECOND EDITION BY JETHRO TULL

PREFACE

The ceremony of a Preface

I think it unnecessary (if not impertinent) to trouble readers with a long account of a short treatise which they have before them. I might, as a Rustic, omit the ceremony of a Preface were it not reasonable to expect that an apology will be required for writing and publishing a book without the usual qualifications of an author.

It was not, indeed, my own inclinations that prompted me to write. Though almost all my life has been a continued sickness, I was so disinclined to become ill with the "Scribbling Disease" that I put off writing more than twenty years before I was prevailed upon by those persons of rank who had seen my manner of planting sanfoin, etc. to commit my thoughts upon husbandry and the descriptions of my engines to paper. Despite the many just excuses I had for declining a task of which I knew myself incapable, their solicitations by letter (enough to make an ordinary volume) I simply could not absolutely refuse.

I had foreseen that words would be needed to express my thoughts properly. This is a misfortune that cannot be concealed after a long confinement within the limits of a lonely farm in a country where I am a stranger, having myself barred from all but low life conversation.[4] However, at first, I did not think this should be too great of a problem as I did not think I should have occasion of many words. I had intended to write no more theory than my notion of *The Pasture of Plants* to show how their roots are naturally adapted to receive the benefit of the hoeing husbandry and had believed that the whole of that might have been comprised in a sheet or two. But books of agriculture came by chance to my hands (I never read any of them before) and occasioned more writing than I initially proposed.

[4] The current editors, as William Cobbett and previous editors have done, have taken this as a plea for assistance (Jethro Tull's objective was to have his work as widely diffused and understood as possible). This assistance has come to include (by the interpretation of many previous editors) an updating of the language to suit modern standards, and, in by this editor, a modification of the language to American English. –A.B. & M.C.

The publication of the First Edition was impossible to supervise due to illness; Second Edition improves connectivity, detail, organization

It is no wonder that the style of this book is as low as the author or the dust that he here treats of: the whole was written during the pains of the stone, and under the ailment of other diseases as incurable and almost as cruel. Connectivity cannot be expected of a book composed by notes written at different times, some in one year, some in others, as something new flowed by a practice different from what was common.

Connectivity aside, I was, by sickness, incapable of assisting when it was transcribed for the press (when many notes were to be inserted) and my scribe did not understand their marks and misplaced many of them: he placed some in the text, some in the margin, some in the wrong chapters, left many out and mislaid more that he never did find (among those were the several weights of my drilled crops and their neighboring crops).[5] My scribe was so little skilled in the country affairs to have sometimes to set the cart before the horse, as he did when he placed the hoeing of turnips before the planting of them: but I presume this mistake will not be followed by any practitioners and that nobody will be badly injured by it, or by any other such like to be found elsewhere in the book. Another injury I was not able to prevent was the insertion of the five chapters of the *Specimen* without separating them.[6] Also, while some things may be properly repeated where used in different places for different purposes, I doubt that this will excuse every repetition the reader will find.[7]

And I had no opportunity of correcting the sheets from the press, nor any friend to do it for me! This might allow some excuse for the faults of the printer—if he had not usurped the prerogative of coining words. All the printer can pretend to say for his, and what I am sure I can truly say for my own faults (which perhaps may be more), is that none of them are willful.

[5] In a supplement, attached to the 1761 edition, Jethro Tull set the number of the page and line before each note to show where it was to belong. The editor of that edition included those notes in the end, without inserting them into the text. William Cobbett, building on the work of 1761, inserted most of them into the text and, finding no direction from Tull, inserted the remainder in a separate chapter. Like Cobbett, the current editors have included all these in the text as directed by Tull, but unlike Cobbett, when not directed by Tull, they have inserted these notes in what seemed to be appropriate chapters. Occasionally, when it seemed appropriate, we disobeyed Tull. –A.B. & M.C.

[6] This mistake was perpetuated by William Cobbett, whose only effort to correct this mistake was inserting notation preceding those five chapters informing the reader that they once belonged to the *Specimen*. We have left these chapters together in the belief that such organization actually improves readability. –A.B. & M.C.

[7] We have not undertaken the elimination of redundant passages as they did not appear obnoxious. –A.B. & M.C.

Excuse for long footnotes

It is doubtful whether the manner of filling the pages with footnotes is a fault.[8] Those who read merely for curiosity may dislike the notes for being out of the mode, but the reader who intends to practice the horse-hoeing husbandry may like the notes all the better because by this means things are brought into the shortest compass: the reader may have in their view in one page as much matter (as might be extended to several sheets by the introductory words which would be necessary) to carry it on in a continued discourse. If anyone shall be so censorious as to say that I used this contracting method to save my own time in writing than their own in reading, perhaps their suspicion may not be very unjust: he who practices agriculture with effect can have little time to spare. But since I cannot pretend to say that this Treatise (as a late author says of his much greater bulk on the same subject) that it is *Multum in Parvo*[9], I may hope in respect of its shortness that it is not *Parvum in Multo*[10] and that brevity may make a dull discourse tolerable. Fine language does not fill a farmer's barn and Truth needs no embellishment from art!

The Second Edition includes extensive response to the unreasonable criticisms and objections to the First Edition

And I also beg the pardon of the "learned writers" whom I am forced to differ in opinion, as well as in learning[11]. I assure them that it is unwillingly and with regret that I do. But no canon has limited what we shall think in agriculture, and none may be condemned for heresy. Every man is a free-thinker and must think according to the dictates of his own reason. Whether he will think reasonably or not is such a freedom that is given now-a-days in speculations into natural philosophy: it is common to see people even in print maintain that there are antipodes and that the earth moves around the sun—without being censured for these and many other formerly heterodox opinions. Everyone may now upon solid arguments contradict Aristotle himself publicly and anywhere (except in schools). My arguments are what I bring for maintaining the principles I have advanced and I dare neither affirm or deny them (myself being not as a competent judge of them as the reader—especially the practicing reader). To the decision of the reader must be left all that is disputable.

The reader's partiality I have no reason to apprehend because it is in some degree the interest of everyone who lives by bread that the true principles be established in agriculture. No principle ought to be allowed as such until it has been thoroughly examined. Truth is like gold, which the more it is tried the brighter it appears, being freed from dross. To be thus examined is the chief design of publishing this essay on tillage and vegetation.

Since great men seem to have made some mistakes of consequence in these matters, it may well be supposed that I have made many more; but if any of these mistakes shall be judged to be of substance, no man shall be more willing than myself to sign their condemnation. I believe the

[8] In this philosophy, we too have attached long footnotes. –A.B. & M.C.

[9] "Much in little" or a condensed work of value – translation by Aaron Brachfeld

[10] "Little in much" or "much of little." A diffuse work (with filler and fluff) translation by Aaron Brachfeld

[11] The editors repeat this plea. –A.B. & M.C.

judicious reader will excuse such inconsequential mistakes that are merely of form and of those which arise from their being improperly expressed: such the judicious reader will construe as near as they can according to their intended meaning, and when by misfortune they may seem to jar in one part, the reader will endeavor to reconcile them by some other part, or by the tenor of the whole.

Excuse for singular examples

I have sometimes, for brevity's sake, produced only one instance instead of many which I could have given. I know that a single instance is not sufficient of itself when there is no other proof, but when a thing is first fully proved in theory, I think one instance of fact in practice may be sufficient for its confirmation. And besides, the practitioner will be abundantly furnished with instances from their own experience. The matters of fact I have related are not like some of those stories told by travelers (hard to be disproved if they are wrong).

Response to pretenders and imposters providing the confusion of misinformation and misrepresentation as if it were refutation

What pretenders or imposters have taught or said of the horse-hoeing husbandry is unknown to me, and I am not answerable for any follies they may have committed since I gave sufficient cautions against them in my preface to the Specimen published for that very purpose two years ago. To magnify the benefits of the horse-hoeing husbandry above what is accurate may be as injurious as to ignorantly undervalue it. If any have gone rashly into the practice of the horse-hoeing husbandry, it is probable that they may rashly go out of it before they rightly know what it is.

Every man is best satisfied with experiments made by himself; therefore I advise him who intends to practice that he would repeat all my trials before he relies upon them—not because I have been unfaithful in the making or relating of any of my experiments (for I only made them in search of the Truth for my own satisfaction): I do not doubt that, if the reader follows the same process, their experiments will succeed as mine did. But by repeating the trials he may very likely draw many more lessons from them than I have.

Supplement of 1750

The theory of Mr. Evelyn's "Of the Pasture of Plants" omitted

The experiment of artificially pulverized soil by Mr. Evelyn seeming to confirm what I had written *Of the Pasture of Plants*, I wanted to insert it into my chapter of tillage as soon as I had read it. But Mr. Evelyn takes no notice that the surfaces of those fine parts, into which the earth is divided by such pulverization, is the vegetable pasture. Therefore, I omit his theory.

Inspiration from mustards and sanfoin responding to tillage

I saw a great mustard plant growing accidentally on the side of a row of horse-hoed peas in land that had been well tilled and dunged[12]. I am in some doubt concerning the height of the great mustard plant because I did not measure it: the idea I had of it came to me four or five years after I saw it. It was the first of the species that I had seen in this country, and having formerly taken half a pint of seed from one single plant of it in Oxfordshire which had been smaller than even one lateral branch of this great mustard plant, I designed to measure the seed it would produce. Unluckily, before the seed was ripe, the people who cut the peas chopped it to pieces with their hooks because it had spread wide and stood in their way.

This last summer I saw the produce of two sanfoin plants carefully weighed. They both grew in the same ground, not far asunder, and were seven years old. One stood single, and its product weighed thirty seven ounces and a half. The other grew in a bunch among many neighbors and when it was dug up its product weighed only three grains. This is only about a five thousandth part of the other. I think that this proves that it is not extravagant to say that one single (or thin) sanfoin plant may produce as much hay as a thousand thick ones. And I have seen greater single sanfoin plants than this!

Practical recommendations in this book must be varied based upon environmental considerations of the farm it will be practiced upon using theories presented here

As to the distances of rows and other matters of practice, I can only tell the beginner what I would do and the reasons from which I proceed (as far as a weak memory and my notes serve me). If the beginner approves of my reasons, they become his own and the beginner may proceed upon them as such. If the beginner doubts my reason, it cannot cost much to satisfy themselves by proper trials.

I have had great crops of turnips in rows thirty-six inches apart that were much greater than I could ever obtain from rows thirty inches apart. But one reason why I prefer to plant rows seventy-two inches apart is that the largest turnips are best for oxen and are pulled up and loaded with the least expense: if the turnips should be as small as the other turnips hereabouts commonly are, the expense of harvest would go a great way into their value. I find that the less densely sown turnips are (*caeteris paribus*[13]) the larger they will be.

But here is a great inconvenience that happens to these turnips (especially when the turnips generally fail, as they did this year): as soon as they begin to head, the lawless people set upon them and, because the roots are covered by soil, they cannot easily know which of the turnips they like until they have pulled them up. These lawless[14] people spoil ten for every one they take. But when

[12] When reading "dunged," understand "fertilized," not just with manure but with vegetable compost, ashes or other agents. Tull's favored "dung" was green manure. This particular mustard plant is further discussed in Chapter 7, Of Hoeing. –A.B. & M.C.

[13] "All other things held constant," a signification describing that this is the only variable being considered. –A.B.

[14] Yet, to speak properly, the actions of these people are lawful: by the law, there can be no enclosures! Every foot of ground that lies without doors is common to these people. But still, I cannot help but thinking that it is very hard, after paying four Shillings to the Pound to the Poor's

the turnips are only grown as big as apples, the lawless people make less waste and carry away as many in a bag as would (when the turnips were mature) fill a wagon. Thus the best crop is soonest destroyed. I confess that this is an objection to which I can give no effectual answer except this: that in a plentiful year, when the turnips stand, the slow growth of sown turnips renders them much sweeter for boiling than the drilled turnips. This draws more of these lawless "customers" to the smaller, sweeter turnips than to the larger drilled turnips.

Continual crops of wheat possible without rotation or manure

The particular scheme of raising continual crops of wheat without dung or fallow is, as yet, still only on probation. But, by the six crops I have had in this continual manner, I see nothing against the continued success of the scheme. It is true that this scheme requires greater care in management than any other branch of husbandry, but the agriculturalist that can do without dung or fallow may easily do better with one or both of them. And there may be such wet, clayey land that the plow cannot well pulverize without the help of dung. And in any sort of land, when it is suspected that the earth of the partitions was not well ordered in the summer, the best remedy is to throw a small quantity of malt dust or other fine manure upon the rows about the month of February. This will strengthen the plants and enable them to send their roots into the intervals earlier in the spring.

Aisle width can be reduced in good land

Against the necessity of the wide aisles that I like best my neighbor tells me that he has had five successive crops of wheat and allows only four feet between each row and its interval. His rows have sometimes been double and sometimes treble, but his ground is better than mine and he bestows more hand-work upon it.

Many will think this continual wheat crop more a curiosity than a profitable enterprise, and in some circumstances it may be so. But by what I can hitherto observe in agriculture, the best management always succeeds best—contrary to the Proverb that says "once in seven years the worst husbands have the best corn," and shows that sometimes—even to this day!—Ceres prefers her Virgilians for their demerits.

Experimental methods of planting wheat

For planting a single crop there are several methods. The narrowest aisle wherein the hoe-plow can be profitably exercised among corn is thirty inches, and if this should be uneven it could not be horse-hoed. Therefore, to keep it even and accessible to the horse-hoe, the seed drill must have two shares thirty inches apart (the horse path being in the middle between them). By this means, the space between rows (whose evenness is not so necessary) will be the parting space. But take care that the point of one share does not incline downwards more than the other, for if it should, it will run very deep into the ground and the other will go very shallow. Also be sure not to

Tax and paying extravagantly for the little hand-work bestowed on my turnips that the best product of my enclosures should not be my own.

let the hoe-plow go forwards and backwards immediately in the same interval, for if it does, the furrows will all lie on the same side, and then at the next hoeing, the plow must go twice the length of each aisle to plow one single furrow. This inconvenience is easily prevented when foreseen. I have had many of these single crops of wheat in double rows, and always observed it to be made very strong by use of the hoe only, but I chose to have the aisles five or six inches wider.

There is another way to have one crop of wheat. It is to go with the treble drill twice instead of once upon each of the broad ridges. This will make sextuple rows with five partitions of seven inches each. I had an example of this the last year on one outside ridge. The first and sixth of these rows standing next to the hoed earth were strong, and so were the third and fourth that stood on top of the ridge. But the second and fifth were standing lower and fell vastly short of the rest. If any of these had had more fine soil under them, I do not doubt but they might have been equal or nearly equal to the other.

The worst error I apprehend the beginner will be liable to is to expect the benefit of pulverization where his land is not pulverized. I had this year in the middle of a field of wheat, about two or three acres, the soil of whose partitions missed one of the hoeings in the precedent summer. The color of this wheat was plainly distinguished from that of the wheat on both sides of it at half a mile's distance in the spring and was not above half the crop at harvest. But if the rest of the piece had not a hoeing more than this had, the whole then being alike poor, it would not have so plainly appeared that the poverty was for want of one more hoeing.

Although wheat, as an exportable commodity, is the fittest for a general improvement, in some particular places, other vegetables such as rape or woad would be more profitable than any sort of corn and I have been told by one who has been long a dealer in rape that he has made it larger and stronger in poor land by horse-hoeing than he could ever make it in the richest land by the common method.

The greatest obstacles to a productive farm are bad laws, ineffective government and disloyal employees

It is the most formidable objection against our agriculture that the defection of servants and laborers is such that few Gentlemen can keep their lands in their own hands. Rather than make nothing of their lands, these Gentlemen rent them for a little to tenants who can bear to be insulted, affaulted, kicked, cuffed and bridewelled with more patience than Gentlemen are endowed with.[15] It is a public calamity that the lands of a country are all or mostly in the hands of rack-renters whose interest it is (or at least they think so) that their lands may never be improved: we need not wonder when we see copy-holders and lease-holders oppose the improvement of their rented land for fear their rents should be raised:

The very different regard that every man naturally has to the interest of his heirs from that of his successors may be seen by the poverty and unimproved conditions of St. Peter's Patrimony in England compared with the hereditary estates of Italy. An English renter has no less honor than an Italian, but the Italian does not fear being turned out by a successor in his lifetime as the English renter is sure to be when his lease is ended if he has improved his farm and will not be able to afford the raise in rent.

[15] Jethro Tull is continuing his comparison begun previously to convey the understanding that the "defective" servants abuse their masters. –A.B. & M.C.

They who impute this misfortune of the land to the loss of the Common Law (which favored agriculture and was to our ancestors a better inheritance than that which came from their parents) pretend to prove that the Statute of Laborers has turned more Gentlemen out of their estates than the Norman Conquest did. But their arguments being too numerous here to be recited, I shall only give them this general answer: the lands of France are occupied with pleasure and profit by the owners (who live well upon them, and leave them planted and improved to their heirs after having paid almost as much in taxes to their King as our tenants pay in rent to their landlords for better land), and yet there is none of our Common Law in France.

In France, everything is decided by trials at discretion. But then, indeed, in France as the magistrates are arbitrary over the people, so is the King arbitrary over the magistrates and in favor of tillage he will not suffer so that the possessors of the land shall be trampled on by their servants and laborers (or other inmates of the country). Servants in France must obey their masters as far as is necessary for carrying on their business and the laborer must be worthy of his hire—for if, when he is able, he will not work neither will he eat. And so in France they are unaccustomed to idleness and none are starved that I can hear of.

This may perhaps serve for an answer to those who assert that there can be no justice without juries, but whatever becomes of our lands, I pray to God to defend us against a French Government in England!

I can hardly believe that the behavior of servants, etc. is so general as it is commonly reported to be: surely the freeholders of counties would petition their respective representatives in Parliament in hopes that so public and heavy a grievance might be redressed by the same power that took away part of the Common Law to restore it in its pristine purity and enable the owners of lands to occupy and improve them as freely as their ancestors might have before 5th Elizabeth. The horse-hoeing husbandry would profitably employ many more hands than the common husbandry and procure more bread for them. But if through the aforesaid unfortunate circumstances it cannot be frequent in South Britain (which seems to be the most proper climate in the world for it), if it could be useful to any other of his Majesty's dominions I shall think my labor amply rewarded by that success.

In England those very inconveniences that attend arable land make the improvement by sanfoin the greater. In this many others as well as myself have found my drill to be very advantageous—not that the drill is necessary for planting sanfoin in all lands (in most soils that are rich and proper, sanfoin will prosper and last with whatever manner so ever it is planted) but in a chalk soil with a poor thin staple, I never knew sanfoin to succeed unless it was properly drilled or else yearly manured at great expense with peat-ash, soot, or coal-ash.

Seed drill necessitated by unskilled labor

The sort of seed which is most served by the drill is sanfoin. My first occasion of making a drill for fine seeds was that it was very difficult to find a man that could sow clover tolerably. The men who tried had a habit (from which they could not be driven) to throw it once with the hand to two large strides and go twice on each cast. Thus, with nine or ten pounds of seeds to an acre, two thirds of the ground went unplanted and the rest was so thick that it did not prosper. To remedy this I made a hopper to be drawn by a boy that planted an acre sufficiently with six pounds of seeds. But when I added to this hopper an exceedingly light plow that made six channels eight inches apart into which two pounds to an acre were drilled, the ground was well planted. This drill was easily drawn by a man, and sometimes by a boy.

Another general and no inconsiderable advantage of the use of the drill is that it can save more than half the seed that is sown and plant the land the better. Hand-hoeing is made easier. They may hand-hoe between the nearest rows if they please, or pull out the weeds without treading on the corn[16]. But the drill is even be serviceable to the old husbandry in some respects, as when land having been plowed dry and lain until the rain comes, its surface is grown so hard that the wheat seed cannot be covered by harrows on drags. Then the drill will make channels, sow the seed and cover it effectually.

Hopes for fully automatic, mechanized agriculture reason for freely sharing plans for making invented machines, and the failure of the engraver to render drawings accurately

The descriptions in the five last chapters are given so that Gentlemen could contrive such Automata to do the business appertaining to tillage without hands[17] at a price that is reasonable to be given to servants and laborers, so that the want of landowners to manage their lands with profit would be satisfied. But I fear my descriptions in the five last chapters, for want of technical words, may not be as perspicuous as I could wish and that there may be some little errors in the plates for the reason that I live at a distance from the engravers. But, I hope there are no errors in any material part and that by the cuts and their explanations all these instruments may be made to perform perfectly.

Every figure of the drill is in its full dimensions where none are given. If the angle of inclination of the slides of the mortise should be six degrees instead of eight, in the wide boxes there described it might do well enough, but in narrow mortises or for drilling rough[18] seeds, eight degrees of inclination are necessary.[19] Eight are not injurious to the widest mortise because in the wide there is not the exactness required in the narrow.

I regret that it happened that it was not in my power to describe in cuts a particular drill for planting turnips between rows of corn (both in the wide and narrow aisles). The advantage is such that the turnips are small at the corn's harvest and do no perceivable damage to the corn, and then afterward grow large by the horse-hoeing husbandry. These turnips, being grazed by sheep in the winter, afford considerable profit and enrich the land for a following spring-crop of corn.

The drill required for this interplanting must have only one share (that must go on the pulverized soil very near to the row) and one wheel only (to go in the middle of the aisle). The

[16] Read "corn" and understand "cereal grain," not "Indian corn." In this case, also understand "desirable crop." –A.B. & M.C.

[17] Not that there is any want of hands to receive a Gentleman's money, but such hands that want as well as are willing to work faithfully at reasonable wages are rare. By their general behavior, most wanting hands resemble more French Dragoons in a time of persecution than servants: it is not long since that the public News gave an account of a noble Lord's being insulted by footmen in the Royal Palace. If this is their manners when polished at court, what idea can be formed of their insolence whilst they follow the plow in the country?

[18] Read "rough," understand the combination of both "rough" texture and "large" size. –A.B. & M.C.

[19] I drill sanfoin with mortises three quarters of an inch wide with the wheels low and, indeed, if I were to make a drill for sanfoin only, even on high wheels, the mortises should not exceed one inch in width—and then eight degrees of inclination would be safer than six.

hopper must be fastened immovably to the plow in such a manner that nothing may take hold of the corn. Such a drill may be drawn by a man.

An unfinished work

One cause that made the three sections of the book—that is to say, the theory, the practical and the description of the tools—the more defective was that all three were too many for me to make perfect at once. Two would have been useless without the third. Therefore, it was better to give but a sketch of all than to have made any two of them never so full and perfect, leaving out the other. If this, my first Essay, should meet with encouragement, it is possible (though barely possible) that I may write a supplement containing amendments and additions to every part, together with answers to objections—which it is impossible for me to answer before they are made or before I have been apprised of them!

—Jethro Tull
of Shalborne in the County of Berks

THE THIRD EDITION
BY DUHAMEL DU MONCEAU

P R E F A C E

About Monceau: (1700-1782) Inspector-General of the French Marine (and had agricultural duties as well), naval engineer, member of the French Academy of Sciences, farmer, forester, fisherman, biologist, chemist, meteorologist, and writer of technical handbooks for the French public on the subjects of science, fishing and agriculture; discoverer of the differences between potash and soda, the similarity between the growth of bones and the growth of trees, the influence of weather on long-term agricultural production trends and efficiencies from climatic advantage for particular crops in particular locations, and the first formal scientist to discover and examine the Horse Hoeing Husbandry.



Henri Louis Duhamel du Monceau (1700-1782), the son of Alexandre Duhamel, lord of Denainvilliers, was born at Paris in 1700. He was a French botanist and engineer and, upon having been requested by the Academy of Sciences to investigate a disease which was destroying the saffron plant in Gâtinais, he discovered the cause in a parasitical fungus which attached itself to the roots, and this achievement gained him admission to the Academy in 1728.

From then until his death he busied himself chiefly with making experiments in vegetable physiology.

Having learned from Sir Hans Sloane that madder possesses the property of giving color to bones, he fed animals successively on food mixed and unmixed with madder and found that their bones in general exhibited concentric strata of red and white while the softer parts showed in the meantime signs of having been progressively extended. From a number of experiments he was able to explain the growth of bones and demonstrate a parallel between the manner of their growth and that of trees.

Along with the naturalist Buffon, he made numerous experiments on the growth and strength of wood, and experimented also on the growth of the mistletoe, on layer planting and on smut in corn.

He was the first, in 1736, to distinguish clearly between the alkalis, potash and soda. From the year 1740 he made meteorological observations, and kept records of the influence of the weather on agricultural production. He was inspector-general of marine, and applied his scientific acquirements to the improvement of naval construction. He was involved in the foundation of the *Académie de marine de Brest*, on 31 July 1752.

He was an inspiration to the economist Adam Smith when he wrote on pins in his *l'Art de l'Epinglier* (1761), "There is nobody who is not surprised of the small price of pins; but we shall be even more surprised, when we know how many different operations, most of them very delicate, are mandatory to make a good pin. We are going to go through these operations in a few words to stimulate the curiosity to know their detail; this enumeration will supply as many articles which will make the division of this labour...The first operation is to have brass go through the drawing plate to calibrate it."

In 1767, du Monceau was elected a member of the Royal Swedish Academy of Sciences

He died at Paris on the 13th of August 1782.

His works are nearly ninety in number, and include many technical handbooks.

Remarks on the Third Edition: first official republication of Tull

It is interesting to note that du Monceau did not speak English, and relied on a translator who did not either. Or, at least, had little understanding of English agricultural terms. This nearly crippled the work, if it were not for Tull's diagrams and experiments, which yielded to du Monceau that which his translator could not.

It is, in this light, more interesting to note that it was du Monceau's work that introduced Tull to the world, for his official government translation of the work was translated itself into many other languages (we were unable to ascertain if those translators knew more about French agricultural terms than the French knew of English agricultural terms).

About the Translation of the Preface to the Third Edition

This preface is presented in two parts: the original French and the English translation (by Mary Choate). The French is not modern French, and is presented as found. The English has been "shopped" and finished to be more beautiful or proper to as minimal a degree as possible so that a more exact understanding of what du Monceau intended could be rendered. This decision was hard,

considering that Latin translated in subsequent Chapters by Jethro Tull, Justin Walker and Aaron Brachfeld is finished to a fine degree, but was made considering the differences between Latin and English is greater than between French and English and thus required more translational assistance.

When previous editors, typesetters and printers erred, Choate (who also transcribed these words) included her interpretation beside the original when possible and simply inserted in place when impossible in parenthesis and with a question mark (like so?). When the meaning of a word is subtle in translation, Choate uses two words to express the one, placing a slash between them like/so. This helps the reader better understand the subtlety of the words and serves to help the reader translate the meaning of the French rather than undertake it fully for them.

Translation is an art of subtlety, and the master is one who provides enough help to the reader that they might furnish for themselves the finer understanding required to interpret what has been accurately translated.

Tull fortunate in his examination by such a qualified scientist, unfortunate that the French spoke poor English

We can think of few of Tull's contemporaries more suitable to introduce Tull to the world. However, his remarkable scientific insight was betrayed by an underlying lack of English. –A.B. & M.C.

The French Version, by Du Monceau

Traité de la culture des terres,
Suivant les principes de M. Tull, Anglais ;
Par M. Duhamel du Monceau, de l'Académie Royale des Sciences, de la Société Royale de Londres, Inspecteur de la Marine dans tous les Ports & Havres de France.
Avec Figures en Taille-douce
A Paris, Chez Hippolyte-Louis Guerin, Librarie, rue Saint Jacques, à s. Thomas d'Aquin.
M. DCC. L.
Avec Approbation & Privilège du Roi.

Preface

M. Tull se retiré à la campagne, s'étant livré tout entier à la culture des terres, forma sur des expériences répétées, un nouveau système d'agriculture, qu'il publia dans un ouvrage assez étendu, qui a eu beaucoup de partisans en Angleterre.

La réputation de ce traité étant parvenue jusqu'en France, M. le Maréchal de Noailles engagea M. Otter[20] à le traduire : mais pour rendre le sens de cet ouvrage (déjà difficile à entendre dans sa propre langue) il ne suffisait pas de savoir l'anglais, il était de plus nécessaire de connaître l'agriculture. Aussi quand tout l'ouvrage fut tranduit, M. Otter convint que son manuscrit avait grand besoin de passer sous les yeux d'un homme instruit des matières qui s'y trouvaient traitées. M. de Buffon se chargea de cette révision, qui l'occupa pendant plus de trois mois.

J'ignorais tout ce que je viens de apporter, lorsqu'au mois de Juin 1748, je reçus une traduction du même ouvrage, qui avait été faire par M. Gottfort, avec une Lettre de M. le Chancelier, qui désirait savoir ce que j'en pensais.

Cette seconde traduction avait les mêmes défauts que celle de M. Otter ; aussi M. Gottfort convint qu'elle ne pouvait pas être imprimée telle qu'il la présentait.

L'intérêt que je prends à tout ce qui peut être avantageux à l'agriculture, le désir de répondre aux vues de M. le Chancelier, la nouveauté des idées de M. Tull, et l'envie d'obliger le traducteur qui courait la risque de voir rester son travail inutile ; ces différents motifs m'engagerent à faire sur la traduction de M. Gottfort à peu près la même révision que M. de Buffon avait faite sur celle de M. Otter.

J'étais presque à la fin de cet ouvrage, quand M. de Buffon, informé que je travaillais sur l'ouvrage de M. Tull, m'apprit comment la traduction de M. Otter lui était tombée entre les mains, et le travail qu'il avait fait pour la corriger ; il ajouta qu'il n'avait pas jugé à propos de la faire imprimer, parce que des idées neuves et utiles que l'ouvrage de M. Tull contenait, étaient noyées dans beaucoup de raisonnements vagues, et qu'il régnait partout une prolixité qui l'empêcherait certainement de réussir. Je lui avouai que j'en avait porté un jugement pareil, et que pour mettre les amateurs d'agriculture à portée de profiter des bonnes idées de M. Tull, j'avais commencé un extrait de son ouvrage. M. de Buffon jugeant que c'était le seul parti qu'il convînt de prendre, eut la politesse de me remettre sa traduction, pour que je puisse la consulter quand il se trouverait de l'obscurité dans celle de M. Gottfort.

Je continuais le travail que j'avais commencé, et m'étant rempli l'esprit des idées et des vues de M. Tull, j'y mis l'ordre qu'il me parut convenable ; supprimant entièrement tout ce qui était étranger au sujet ; abrégeant ce qui me semblait trop étendu, détaillant les méthodes ordinaires de cultiver les terres, quand cela me paraissait nécessaire pour faire apercevoir les avantages de la

[20] De l'Académie des Belles-Lettres, mort en Octobre 1748

nouvelle méthode ; ajoutant des expériences pour confirmer le sentiment de l'auteur ; ou pour avertir qu'il faut être en garde lorsque les principes de M. Tull ne sont pas assez bien constatés. Enfin sans suivre servilement mon auteur, j'ai essayé de rendre l'esprit de la chose sous une forme toute différente.

Je ne dois pas oublier de prévenir le lecteur qu'il ne trouvera pas les matières épuisées, même dans les chapitres où je traite un objet en particulier, comme des racines, des feuilles, de la nourriture des plantes, etc. car j'ai essayé de ne rapporter que ce qui appartient immédiatement à mon objet, ou ce qui est nécessaire pour l'intelligence du nouveau système d'agriculture.

Malgré les additions qui m'appartiennent en entier, et qui font une partie considérable de l'ouvrage que je présente au public, je ne crois pas avoir rien omis de ce qui est intéressant dans le livre de M. Tull, qui néanmoins en anglais est un petit in-folio.

Plan de l'Ouvrage

Ce traité est divisé en deux parties. On expose dans la première les principes de la nouvelle agriculture, et on en donne des applications à la culture de plusieurs plantes utiles ; cette partie contient vingt et un chapitres. La seconde partie est destinée à décrire les instruments qui sont nécessaires pour cultiver les terres suivant les nouveaux principes.

Je vais donner une idée du sujet de chacun de ces chapitres, ce qui me fournira l'occasion de rapporter certains faits intéressants qui m'ont échappé dans la composition de l'ouvrage.

Dans le premier chapitre on traite sommairement des racines ; il n'y est point question de toutes les distinctions que les botanistes ont établies ; ni d'un examen assidu et délicat qu'un physicien pourrait faire des organes qui les composent. Il suffit pour l'intelligence de la nouvelle culture de distinguer les racines en pivotantes, qui s'enfoncent verticalement dans la terre, et en rampantes qui s'étendent parallèlement à la surface du terrain.

Les racines pivotantes servent principalement à affermir les grandes plantes ; et les chênes, les noyers qui ont des racines de cette espèce, sont moins sujets à être renversés par le vent que ceux qui n'en ont point.

On ne nie pas que les racines pivotantes ne pompent un suc nourricier très-avantageux aux plantes ; car pourquoi la vigne, le sainfoin, la luserne (alfalfa), et tant d'autres plantes flexibles qui ne courent point risque d'être renversées par le vent, jetteraient-elles des racines à une si grande profondeur en terre, si elles n'en tiraient pas de la nourriture ? Mais il est certain que les racines rampantes qui contribuent aussi à affermir les plantes dans la terre, sont bien plus propres que les pivotantes à recueillir les sucs nourriciers.

Il est d'observation que les racines rampantes s'allongent d'autant plus qu'elles sont plus près de la superficie, qu'elles sont plus à portée de recevoir les influences du Soleil, des rosées, de l'air, surtout quand des labours réitérés ont ouvert des passages aux racines, qui suivant nos expériences, s'allongent et se multiplient proportionnellement à la facilité qu'elles trouvent à s'étendre. C'est ce qu'on s'est proposé d'établir dans ce chapitre, et c'est ce qu'on aurait pu prouver par bien des expériences qu'on a supprimées pour ne point trop allonger ce petit ouvrage.

Sans prétendre approfondir ce qui regarde les feuilles, le second chapitre est destiné à l'exposition des différents sentiments qui ont partagé les auteurs sur leur usage. Les uns ont regardé la feuille comme les poumons des plantes ; ils ont prétendu qu'elles contenaient des réservoirs remplis d'un air élastique, qui de là se distribuait dans toutes les parties des plantes ; d'autres ont crû que la sève était portée dans les feuilles pour y recevoir une certaine préparation qui la rendait propre à servir ensuite à la nourriture de toute la plante ; ce qui supposait une circulation de la sève qui n'est pas encore bien établie.

On s'est assuré par des expériences bien faites que les feuilles aspirent l'humidité des pluies et des rosées ; elles peuvent donc être regardées comme des organes qui servent à la nutrition des plantes. Enfin il est tout aussi-bien prouvé que les plantes transpirent très abondamment par leurs feuilles. D'où on conclut qu'elles font des organes destinés à opérer une sécrétion très importante à l'économie végétale.

On n'a pas crû devoir donner la préférence à un de ces sentiments : mais que tous ou une partie de ces usages aient lieu, il reste toujours pour constant que les feuilles sont des organes très utiles aux végétaux : conséquence qui est confirmée par plusieurs observations qui sont rapportées dans ce second chapitre. Nous pourrions leur en joindre un bien plus grand nombre : mais nous n'avons pas crû devoir en supprimer quelques-unes qui sont très-conséquentes, et qui nous ont échappé dans la composition de notre ouvrage.

1°. Si on coupe la moitié ou les deux tiers des feuilles d'un jeune arbre qui est en pleine sève, on s'aperçoit au bout de deux ou trois jours que cet arbre a perdu sa sève, l'écorce qui avant ce temps se détachait aisément du bois, y reste très-adhérente. Avant le retranchement des feuilles, on aurait pu écussonner ce jeune arbre ; un jour après qu'on les a retranché, il n'est plus possible de placer l'écusson ; l'arbre est donc affaibli par la soustraction des feuilles : c'est la conséquence qu'on peut tirer de l'observation que nous venons de rapporter.

2°. Un saule, un peuplier, un orme qu'on laisse croître sans l'étêter, subsiste un siècle sans que sa tige se creuse ; au contraire leur tige se pourrit assez promptement quand on en forme des têtards ; le retranchement répété des branches et des rameaux leur cause donc un tort sensible ; c'est ce que l'expérience précédente prouve évidemment.

3°. Il n'y a que ce petit chiendent (couch grass) à feuille fine et déliée, que cette herbe qui forme les beaux gasons d'Angleterre, qui puissent résister à être tondus de très près, ou par la faulx, ou par les troupeaux, toutes les autres plantes périssent.

On peut conclurre des expériences que nous venons de rapporter, comme de celles qui sont dans le second chapitre, qu'on fait un tort considérable aux sainfoins et aux lusernes quand on les fait paître trop souvent par le bétail, et qu'il n'est peut être pas aussi avantageux qu'on se l'imagine de faire paître par les troupeaux les blés qui sont trop forts.

Quelle est la nature du suc nourricier que les plantes tirent de la terre ? C'est une question à laquelle il est bien difficile de répondre ; car d'un côté la fertilité que les différents engrais donnent à la terre, semble prouver que la sève est composée de sels, d'huile, et des autres substances que la chimie sait retirer des plantes. Mais la fertilité des terres sablo-neuses lorsque l'eau ne leur manque pas, et le succès avec lequel nous avons élevé différentes espèces de plantes dans de l'eau très pure, sont des faits qui semblent indiquer que la sève est plus simple qu'on ne se l'imagine, et que les sucs doivent leur modification aux organes de la plante.

M. Tull pense que la nourriture des plantes n'est autre chose qu'une terre réduite en poudre très fine ; et nous avons essayé dans le troisième chapitre de donner à ce sentiment toute la vraisemblance dont il est susceptible ; néanmoins il est probable que les substances intégrantes de la sève, doivent être dissolubles dans l'eau, et les molécules de terre ne paraissent pas avoir cette propriété. Quoi qu'il en (soit - sait ?), si nous parvenons à augmenter la fertilité des terres, nous aurons lieu de nous consoler de l'incertitude qui regne sur la nature du suc nourricier.

Il s'agit dans le quatrième chapitre d'une question qui est encore fort embarrassante ; aussi est-elle une suite de celle dont on a parlé dans le chapitre précédent. Toutes les plantes se nourrissent-elles d'un même suc qu'elles tirent de la terre ? M. Tull le pense : mais bien des auteurs croyent que chaque plante ne tire de la terre que les sucs qui lui font propres : d'où il suivrait qu'une terre pourrait être épuisée pour une sorte de plante, et ne l'être pas pour les autres. Si les fermiers remarquent que l'orge épuise plus la terre pour le blé suivant, que ne fait l'avoine, c'est, dira-t-on,

qu'il y a plus de ressemblance entre les sucs dont l'orge se nourrit, et ceux qui conviennent au blé, qu'entre les sucs nourriciers de l'avoine et ceux du froment. De même on observe que dans une terre qui a été longtemps occupée par une espèce qu'on y planterait y réussiraient mal : mais on pourrait se promettre plus de succès en les remplaçant par des arbres fort différents. Ces faits, et bien d'autres que nous avons rapportés dans le corps de l'ouvrage, semblent ne pas convenir à l'identité de la sève pour toutes les plantes. Mais comme il y a aussi beaucoup d'observations qui lui sont favorables, nous nous sommes contentés de discuter les deux sentiments sans prendre aucun parti ; la question subsiste, et elle mérite bien que les physiciens amateurs de l'agriculture, en sassent l'objet de leurs recherches. Mais ce que nous croyons avoir assez bien prouvé, c'est qu'un des principaux avantages qu'on se procure en laissant les terres sans les ensemencer pendant l'année de jacheres, consiste à avoir assez de temps pour multiplier les labours autant qu'il est nécessaire pour ameublir et soulever la terre ; en un mot pour la disposer à recevoir le froment qui est le plus précieux et le plus délicat de tous les grains. L'espèce d'une année n'est pas trop pour cela ; car quand on dit qu'il faut donner trois ou quatre labours à une terre qu'on prépare pour le froment, il est évident qu'on ne lui procurerait presque aucun avantage, si on laissait un trop petit intervalle de temps entre ces labours ; car si par un premier labour on a reversé la terre, si on a enterré l'herbe, un second labour donné avant que l'herbe fût pourrie, avant que la terre fût imprégnée des qualités que le soleil et les météores peuvent lui donner, ce second labour remettant la terre à peu près dans le même état où elle était avant le premier, serait nuisible, ou du moins peu avantageux.

Nous avons commencé à faire apercevoir la nécessité des labours, nous insisterons sur ce point dans le cinquième chapitre ; car quelque bonne que fût une terre, les plantes n'en tireraient pas un grand avantage, si leurs racines n'avaient pas la liberté de s'étendre pour en tirer les sucs : une terre trop endurcie y formerait un obstacle insurmontable ; il faut donc la briser par les labours, et rien ne prouve mieux cette vérité que la grande fertilité des potagers qu'on a défoncés.

On croit donc pouvoir poser comme principe, que plus on divise les molécules de terre, plus on multiplie les pores intérieurs de la terre, et plus on la met en état de fournir de la nourriture aux plantes.

Il s'agit dans le sixième chapitre dans moyens qu'on peut employer pour faire cette division ; les labours l'operent mécaniquement, le feu (may have had a line cut off) par voie de calcination, et les fumiers au moyen de la fermentation. Mais les fumiers alterent toujours un peu la qualité des productions, et on n'est pas maître de s'en procurer autant qu'on en aurait besoin, au lieu qu'on peut multiplier les labours autant qu'on le veut, et sans craindre d'altérer la qualité des fruits. Les fumiers peuvent bien fournir quelque substance à la terre, mais par les labours réitérés on expose successivement différentes parties de la terre aux influences de l'air, du soleil, et des pluies, ce qui les rend propres à la végétation.

Les terres qui ont resté longtemps en friche, doivent être labourées avec des précautions particulières dont on est dispensé quand il s'agit de terres qui ont été cultivées sans interruption, c'est ce qui nous a engagés à nous étendre beaucoup dans le chapitre septième, sur le défrichement des terres. A cette occasion nous avons détaillé la façon de brûler les terres, comme je l'ai vu pratiquer en Bretagne, et dans d'autres provinces du Royaume. M. Tull désaprouve cet usage ; il est néanmoins d'expérience que par cette pratique on communique aux terres une fertilité qui dure plusieurs années ; et il faut bien que les fermiers en soient convaincus, puisqu'ils s'engagent à une dépense considérable en journées d'ouvriers, et à une consommation de menus bons, qui dans certains pays n'est pas indifférente.

Au reste il est certain qu'en Normandie on répand de la chaux sur les guérets pour augmenter leur fertilité ; et il me semble apercevoir quelque parité entre ces deux façons de fertiliser les terres.

Les bois, les landes et les prés, doivent être défriché avec des précautions particulières, que nous avons rapportées dans le même chapitre : mais il convient d'ajouter à ce que nous avons dit des moyens de procurer l'écoulement des eaux surabondantes, que nos fermiers forment dans leurs terres de profonds sillons qu'on pourrait comparer à de petits (fossés ?) au moyen d'une forte charrue qui a deux écussons ou deux grands versoirs fort évasés, avec un soc long, pointu, et figuré en dos d'âne par la partie supérieure. Ces charrues n'ont point de coutre, parce qu'il ne s'agit pas de couper une terre endurcie, il ne faut qu'ouvrir dans une terre labourée un profond et large sillon que tienne lieu d'un petit fossé.

Les différentes espèces de terre exigent qu'on les laboure différemment, et avec différentes espèces de charrue. Il nous a paru convenable d'en donner une idée dans le chapitre VIII, sans néanmoins entreprendre de décrire toutes les façons de labourer ; celles qui sont usitées dans notre seule province, auraient fourni la matière d'un chapitre beaucoup plus étendu que celui dont il s'agit. Nous croyons cependant devoir ajouter à ce qui y est dit, que dans les terres sabloneuses quand on veut labourer en billons, c'est-à-dire, quand on veut élever une éminence en dos d'âne, d'un pié et demi ou deux de largeur, entre deux grands sillons, on laboure quelquefois la terre à plat, on la sème, et on enterre le grain avec la herse ; puis on forme à deux piés les uns des autres de profonds sillons avec une charrue faite exprès, qu'on nomme à billonner, elle n'a point de coutre, mais un soc long et étroit avec deux grands versoirs fort évasés du côté du manche de la charrue, et échancrés en dessous, de sorte que cette charrue fait par sa pointe un coin qui ouvre la terre, le milieu des versoirs la renverse sur les côtés, et leur extrémité la plus évasée et échancrée aplanit cette terre, ce qui donne au billon une forme en dos d'âne très régulière : mais cette façon de labourer n'est pratiquable que dans les sables ; une telle charrue corroyerait les terres argilleuses, dans lesquelles même le soc aurait peine à s'ouvrir un passage.

Tous les différents labours dont on parle dans ce chapitre, pourront être faits indifféremment par des chevaux, des mulets ou des bœufs ; chacun pourra se conformer à l'usage de son pays, quoiqu'il fût à desirer qu'on fit plus fréquemment usage de bœufs, puisqu'on épargnerait beaucoup de chevaux, et qu'on multiplierait un animal qui augmente de prix lorsqu'il devient plus âgé.

Ce détail sur les différentes façons de labourer les terres, était nécessaire pour faire mieux comprendre les avantages de la nouvelle culture, dont les principes fondamentaux sont rapportés dans le neuvième chapitre. Ils se réduisent à bien préparer la terre qu'on doit ensemencer, à choisir de bonne semence, qu'on ne doit point jeter à profusion, comme on fait ordinairement, mais qu'il faut distribuer convenablement. Enfin quand les plantes sont sorties de terre, il ne faut pas les abandonner à elles-mêmes, il les faut cultiver de temps en temps comme on fait les plantes potageres : si celles-ci réussissent mal quand on néglige de les cultiver, pourquoi n'en serait-il pas de même des grains qui font un objet considérable de nos revenus ? Les habitants de quelques provinces de France[21] et d'Angleterre, cultivent à bras d'homme leurs fromens à mesure qu'ils croissent ; et ils sont dédommagés au temps de la récolte d'un travail aussi pénible. Combien ces labours seraient-ils plus avantageux s'ils étaient faits à moins de frais ? On y parviendra en suivant la méthode de M. Tull, qu'on trouvera amplement détaillée dans le chapitre X. En voici une idée générale.

[21] Les terres du Haut-Gatinois retiennent l'eau, ce qui oblige les fermiers de labourer par planche, et même de n'ensemencer que la partie la plus élevée des planches, de sorte que plus de la moitié de la terre reste vuide (vide?) de grain jusques vers le milieu de printemps; alors les eaux étant retirees, et la terre (dessechée ?), ils labourent à bras cette terre qui n'était point ensemencée, et ils y sement des navets, des feves, des pois, etc leur intention se borne à la vérité à tirer un profit de toute leur terre. Mais il est certain que le grain qui avait été semé sur le milieu des planches, tire un avantage sensible de ces labours.

Il faut d'abord labourer les terres à huit ou dix pouces de profondeur ; et M. Tull propose pour cela de se servir d'une forte charrue qui a quatre coutres et un soc fort large ; quand la terre est bien préparée il la faut semer ; mais au lieu de jeter beaucoup de semence à la main, et sans précaution, il la faut distribuer par rangées, suffisamment écartées les unes des autres, et y placer les grains à la profondeur et à des distances convenables ; c'est ce qu'on peut faire promptement et par une seule opération avec un semoir inventé par M. Tull. Enfin à mesure que les plantes croissent, il faut labourer la terre qu'on laisse entre les rangées ; ce qui se fait avec une charrue légère qui n'a point de roue, et au moyen de laquelle on peut labourer tout près des rangées sans endommager le grain ; pour moi je compte me servir d'une petite charrue que j'ai fait faire pour labourer les semis de bois, comme je l'expliquerai ailleurs. On trouvera à la fin de ce volume la description de cette charrue.

Faut-il mettre plus de grains dans les terres grasses que dans les maigres, ou le contraire ? C'est une question qui partage depuis longtemps les auteurs d'agriculture. Ceux qui tiennent pour le premier sentiment, disent que les terres grasses sont en état de nourrir un plus grand nombre de plantes : mais les autres se fondent sur deux raisons bien fortes ; savoir (?) que le froment supporte mieux les rigueurs de l'hiver dans les terres fortes, que dans les maigres ; et de plus, que le froment talle et drageonne beaucoup plus dans les terres fortes et substantielles que dans les légères. Comme suivant la nouvelle culture on doit avoir égard à la vigueur des plantes pour semer les grains plus ou moins écartés les uns des autres, il s'ensuit qu'il faut mettre moins de grain dans la terre qui fournira des plantes plus vigoureuses. Mais dans quelque terre que ce soit, on consomme bien moins de semence en suivant la méthode de M. Tull, qu'on ne fait ordinairement.

Si un fermier diminuait ainsi sa semence sans changer ses usages, il courrait risque de ne rien recueillir ; car comme nous le prouvons dans le onzième chapitre, les mauvaises herbes prendraient le dessus du blé : mais les labours que M. Tull conseille de faire pendant que les blés sont en terre, remédient à cet inconvénient en détruisant la plus grande partie de ces plantes nuisibles.

Le choix des semences qui fait le sujet du douzième chapitre, est digne d'attention. 1o. A l'égard du froment, le nouveau est préférable au vieux, parce que presque tous les grains levent, on peut employer celui de l'année précédente, quoique plusieurs grains restent inutiles : mais celui de trois ans ne vaut ordinairement rien, soit parce que les germes se sont altérés, soit parce que les insectes en auront détruit une partie.

2°. On trouve dans plusieurs ouvrages d'agriculture, des recettes qu'on prise beaucoup pour procurer le développement des germes, en mettant les grains infuser dans certaines liqueurs.

Nos fermiers trempent leurs blés dans l'eau de chaux, et ils prétendent que la chaux empêche leurs blés de devenir noirs et charbonnés. Je ne suis point en état de décider positivement sur ce point, non plus que sur l'excellence des liqueurs dont j'ai parlé plus haut, quoique j'aie fait il y a quelques années des expériences qui me paraissaient propres à me faire connaître ce qu'on doit raisonnablement attendre de ces pratiques ; j'en fais actuellement de nouvelles, et si elles m'apprennent quelque chose de satisfaisant, je ne manquerai pas d'en informer le public.

3o. On estime qu'il est avantageux de changer de temps en temps de semence, il m'a même paru que l'expérience justifiait cet usage : mais la plupart des auteurs pensent qu'il convient d'ensemencer les terres avec du grain qui ait été recueilli dans un terrain plus maigre que celui qu'on cultive. M. Tull croit au contraire qu'il faut tirer les semences des meilleurs terrains : cette question est discutée et non décidée dans le corps d'ouvrage : mais l'usage assez constant de nos fermiers est de tirer les semences des meilleures terres, (ou/on ?) encore d'acheter par préférence le blé des glaneuses ; comme il a été ramassé épi à épi, il est très net de mauvaises graines, et les grains sont ordinairement bien conditionnés ; ce qui est conforme au sentiment de M. Tull.

Enfin il y a des auteurs même assez bons, qui croient que les grains changent quelquefois de genre : que le froment, par exemple, dégénere en seigle ou en ivraie, et le blé de Mars en orge. Ils

assurent même qu'on trouve quelquefois des grains de seigle ou d'ivraie dans les épis de froment, et des grains d'orge dans les épis de blé de Mars. J'ai inutilement cherché des grains de seigle ou d'ivraie dans les épis de froment ; car il ne faut pas prendre pour du seigle ou de l'ivraie de petits grains coulés qui se trouvent à la pointe des épis, et qui ordinairement ne levent pas.

M. le Chevalier de Laumoi mon voisin de campagne et mon parent, a voulu constater avec la plus grande exactitude ce qui regarde le blé de Mars, et ce fait méritait de l'être, parce qu'on ne trouve point à acheter de ce grain qui ne soit mêlé avec un peu d'orge ; de même qu'il est rare de trouver du froment absolument exempt de seigle.

Il fit trier grain à grain assez de blé de Mars pour ensemencer un arpent de terre ; et il fit semer un autre arpent avec de la semence non triée, et telle qu'on la trouve au marché ; il ne fut point surpris au temps de la récolte de trouver de l'orge dans cet arpent, puisqu'il en avait semé, il endevait recueillir : mais dans l'autre où il était assuré de n'avoir point semé d'orge, il n'en trouva pas un épi, et il eut beau examiner les épis, il n'y trouva pas un grain d'orge. Si donc on trouve un peu de seigle dans le froment, et un peu d'orge dans le blé de Mars, c'est parce que ces grains se sement dans la même saison, dans des terres semblablement préparées, ils se récoltent dans le même temps, on les serre dans les mêmes granges ; en voilà plus qu'il n'en faut pour produire le mélange qu'on observe ; presque toujours le merveilleux se dissipe quand on a examiné les faits avec assez d'attention.

Après avoir détaillé suffisamment les principes généraux qui servent de (base/base ?) à la nouvelle culture, il convenait d'en faire l'application à culture particulière de quelques plantes, nous avons choisi pour exemple les gros navets, le froment, le sainfoin et la luserne.

Dans le treizième chapitre on donne la culture ordinaire des navets, et on expose dans le quatorzième la culture de cette plante suivant les principes de M. Tull. Nous avons de même employé deux chapitre, le XV et le XVI, à exposer la façon de cultiver le froment suivant l'ancien usage, et suivant les nouveaux principes.

Mais comme le froment est le plus précieux de tous les grains, nous nous sommes plus étendus sur ce qui regarde sa culture, et nous avons employé le dix-sept et le dix-huitième chapitre pour détailler les maladies du froment, qu'on peut prévenir en partie en suivant les principes de M. Tull.

Avant d'abandonner le froment ; il convient de rapporter une expérience que j'ai faite en petit, pour comparer les deux cultures.

J'ai fait labourer à la bêche un parallélogramme de terre ABCD (Pl. III.) j'en ai fait semer une moitié AEFD à l'ordinaire, et l'autre par rangées semblables à GHIK, qui étaient éloignées les unes des autres d'environ quatre piés, et les grains étaient dans les rangées à six pouces les uns des autres. Ce petit champ fut semé vers la fin de Décembre. Dans le mois de Mars suivant je fis labourer à la bêche la terre comprise entre les rangées ; quand le blé des rangées montait en tuyau, je fis donner un second labour ; et enfin on en donna un troisième un peu avant qu'il entrât en fleur.

Quand ce blé fut en maturité, tous les grains du milieu du carré AEFD, n'avaient produit qu'un, deux, trois, quatre, quelquefois cinq, et rarement six tuyaux ; au lieu que les grains des rangées avaient produit depuis dix-huit jusqu'à quarante tuyaux ; et les épis des rangées étaient beaucoup plus longs et plus fournis de grain que ceux du massif : mais les oiseaux ayant dévoré le grain avant sa maturité, nous n'avons pu comparer les produits.

Nous remarquons expressément qu'il faut comparer le produit des grains qui avaient été semés au milieu du massif, avec le produit des grains des rangées, parce que le pourtour du massif est presque dans le même cas que les rangées. Et c'est pour cette raison que le long des vignes et des chemins, le blé est plus beau qu'au milieu des pièces.

Le dix-neuf et le vingtième chapitre sont destinés à exposer la culture du sainfoin et de la luserne.

Nous avons beaucoup insisté dans ces chapitres sur les précautions qu'on doit prendre pour consercer la graine de sainfoin, parce que M. Tull les croit nécessaires ; néanmoins, nos fermiers conservent très bien cette graine, en l'étendant assez mince dans un grenier, et en la remuant de temps en temps.

Nous avons fait dans le vingt-unième chapitre qui termine la première partie de notre ouvrage, un parallèle de l'ancienne et de la nouvelle culture qui rendra très sensible les avantages qu'on peut espérer de la méthode, que nous proposons.

Nous n'avons évalué le produit de nos terres qui sont réputées assez bonnes, qu'à quatre, cinq, ou au plus six pour un ; c'est-à-dire, qu'un fermier qui seme cent septiers de froment, ne peut guère espérer qu'un récolte de cinq à six cens septiers ; et Columelle n'estimait pas que son terroir d'Italie produisît davantage. Il est vrai qu'il y a certaines terres qui rendent dix pour un : mais quand nous parlons du produit des terres, c'est une estimation moyenne prise sur toutes les terres qui composent une grosse ferme.

Pline néanmoins parle de la grande fertilité de certaines terres qui rendent cent ou cent cinquante pour un. Il ne serait pas difficile de donner des exemples d'une fertilité encore plus grande, puisqu'en cultivant quelques grains de froment dans un potager, il est commun de les voir produire produire chacun quarante et cinquante épis ; et chaque épi contenir quarante ou cinquante grains, ce qui fait seize cens, ou deux mille, ou deux mille cinq cens grains pour un. Or s'il est possible de parvenir en grand à cette fertilité, c'est assurément en suivant les principes de M. Tull, puisque sa culture est assez semblable à celle qu'on donne aux plantes potageres ; au reste en engageant les autres à en faire l'épreuve, je ne prétens pas m'en dispenser ; et j'ai déjà fait des préparatifs pour la faire en grand.

Ce que nous avons dit en faveur de la nouvelle façon de cultiver les terres, paraît suffisant pour engager les amateurs d'agriculture à en faire l'essai ; et suivant le succès de leurs premières éprouves, ils pourront avec connaissance de cause faire valoir de cette façon une plus grande ou une moindre portion de leur domaine. Car quand on serait bien assuré d'augmenter ainsi les récoltes du froment, il pourrait y avoir de solides raisons qui engageraient à n'employer la nouvelle façon de cultiver les terres, que pour une portion une portion de domaine. Je n'entreprendrai point de détailler ici toutes ces raisons, il me suffira d'en rapporter quelques-unes que je vais présenter sous la forme l'objection.

Ire Objection. Suivant la nouvelle méthode toutes les terres étant perpétuellement ensemencées en froment, le fermier ne recueillerait point d'avoine pour la nourriture de ses chevaux, ni d'orge pour l'engrais de ses volailles.

Reponse. Cette objection est forte, néanmoins je prie qu'on fasse attention que les terres qui sont les meilleures pour produire du froment, sont rarement très bonnes pour l'avoine, et que celles qui sont les plus propres pour produire ces menus grains, fournissent ordinairement peu de froment. Par exemple, les terres de Beausse produisent ordinairement plus de froment, et moins d'avoine que les terres du Haut-Gatinois.

Ce principe une fois établi, il me semble qu'il serait du bien général qu'on semât toutes les terres de Beausse en froment, et toutes celles du Gatinois en avoine ; le laboureurs de l'une et l'autre province y trouveraient leur compte, et le plus grand produit des terres tournerait à l'avantage du public. Mais sans changer de province j'ai souvent remarqué qu'une partie des terres d'une grosse ferme était très propre pour le froment, pendant qu'une autre n'était bonne que pour les menus grains. Dans ce cas un propriétaire serait l'avantage de son fermier en lui permettant de déranger les (solles/folles ?) pour les employer à produire l'espèce de grain qu'il saura par expérience y mieux réussir.

On peut appliquer aux autres menus grains ce que je viens de dire de l'avoine ; ainsi je crois avoir répondu à la première objection.

2ème Objection. Le bétail est un objet lucratif pour le fermier ; nécessaire au public, et de plus, avantageux aux terres par le fumier qui les fertilise, même dans les principes de M. Tull. En suivant la nouvelle méthode, toutes les terres seraient cultivées, et continuellement occupées par des grains ; de sorte qu'il n'y aurait ni chaume, ni guérets pour servir de pâture aux troupeaux et au gros bétail ; ainsi plus de bestiaux, point de consommation de fourrage, point de fumier, point d'engrais pour les terres, etc.

Reponse. Je crois que cette objection n'a point échappé à M. Tull, et qu'il compte destiner une partie de ses terres à élever des raves, des navets, et d'autres herbages que les Anglais appellent des pâturages artificiels, qui suivant lui subviennent au besoin du bétail. Ce qu'il y a de certain, c'est que M. Tull avance dans plusieurs endroits de son ouvrage qu'il fait peu de cas de pâtures ordinaires, ni de prés naturels, et qu'au moyen d'une petite quantité de terre qu'il cultive soigneusement en pâturage artificiel, il entretient ses bestiaux en meilleur état que ses voisins.

On ne sera point révolté par cette allégation, si on fait attention qu'un arpent de bon pré produit plus d'herbe que six arpents de jacheres ou de chaumes, et qu'un seul arpent de luserne produit plus d'herbe que six arpents de bon pré ; ce qui fait apercevoir que le produit d'un bon arpent de luserne supasse celui de trente ou trente-six arpents de jachere ou de chaume ; si cela est, ne doit-on pas accorder à M. Tull qu'il est plus avantageux de faire une petite réserve de ses terres pour la subsistance du bétail, que de les mal cultiver toutes au préjudice de la récolte, qui est un objet bien essentiel.

D'ailleurs combien y a-t-il de particuliers dans le Royaume dont le domaine se borne à huit, dix, ou douze arpents de terre qu'ils font labourer à prix d'argent par les fermiers voisins ; ceux-là n'ayant ni chevaux ni bétail, sont infiniment intéressés à augmenter leur récolte de froment, et ils se trouveront bienheureux si en pratiquant la nouvelle culture ils obtiennent de douze arpents une récolte aussi considérable que dix-huit ou vingt leur auraient fourni en suivant l'ancienne.

Les cinq chapitres de la seconde partie, sont entièrement destinés pour la description des charrues, semoirs, et autres instruments que M. Tull a imaginés pour cultiver les terres. On avoue que la description des semoirs est longue, et néanmoins quelquefois assez obscure. On s'est cependant donné tous les soins possibles pour bien rendre l'Anglais ; on a même eu l'attention de faire revoir le chapitre par différentes personnes qui savent très bien l'Anglais.

Nous y avons ajouté une herse roulante, dont nous avons parlé dans la première partie, et une charrue légère, chapitre VI, fort simple, que nous employons pour cultiver nos (semis ?femis ?) de bois, et qui pourrait être substituée à la charrue légère de M. Tull.

Le chapitre VII est la traduction d'un passage de l'Abrégé des Transactions Philosophiques par Baddam, tom. I. p. 248, qui rapporte la description et les usages d'un semoir Espagnol inventé par Dom Joseph Lucatello, dont il est parlé dans les Transact. Philos. No. 60. p. 1056. il était juste de faire mention d'une façon de cultiver les terres, qui a mérité des appaudissements, et qui pour les choses essentielles a beaucoup de rapport avec celle de M. Tull. Et un Espagnol digne de foi m'a assuré que cette méthode qui a été imaginée il y a près de cent ans, se pratique encore dans quelques provinces d'Espagne.

Nous avons annoncé dans un des derniers volumes des Mém. De l'Académie, que nous ferions des expériences sur la conservation des blés. Il convient d'avertir qu'elles sont suivies avec toute l'exactitude possible ; et nous espérons être dans peu en état d'en faire part au public.

Ce fera en quelque façon la seconde partie de cet ouvrage ; et nous n'avons épargné ni soins ni dépense pour qu'il ne reste rien à désirer sur un sujet aussi avantageux au public.

TRAITÉ

English Translation, by Mary Choate

Treatise of the cultivation of the earth,
Following the principles of Mr. Tull, Englishman;
By Mr. Duhamel du Monceau, de l'Academie Royale des Sciences, de la Societe Royale de Londres, Inspector of the Navy in all the ports and harbors of France.
With Figures in intaglio
In Paris, House of Hippolyte-Louis Guerin, Bookstore, Saint Jacques street, to s. Thomas d'Aquin.
1750
With approval and license of the King.
Preface

A celebrated and necessary new system of agriculture

Mr. Tull retired to the country, gave himself up in entirety to the cultivation of the earth, formed on some repeated experiments a new system of agriculture that he published in a work well enough heard of, that has many followers in England.

Translation difficulties due to lack of skilled translators

The reputation of the treatise having just come to France, my Lord the Marshal of Noailles engaged Mr. Otter[22] to translate it: but for putting the sense of this work (already difficult to understand in her proper language) it did not suffice to know English, it was also necessary to have knowledge of agriculture. Also when the whole work was translated, Mr. Otter admitted that his manuscript had great need of being passed under the eyes of a good man instructed in these materials (of agriculture?) that were discussed in the work. Mr. de Buffon charged himself to this revision, which occupied him during more than three months.

I had no knowledge of all this which I have just related, when in the month of June 1748, I received a translation of the same work, which had been made by Mr. Gottfort, with a letter from my Lord the Chancellor, who desired to know what I thought of it.

This second translation had the same faults as that of Mr. Otter; also Mr. Gottfort admitted that it could not have been printed in the manner that he presented it.

The interest that I take in all that could be advantageous to agriculture, the desire to respond to the views of my Lord the Chancellor, the newness of the ideas of Mr. Tull, and the want to oblige the translator who ran the risk of seeing his work remain unusable; these different motives engaged me to make on the translation of Mr. Gottfort almost the same revision that Mr. de Buffon had made on that of Mr. Otter.

I was almost at the end of this work, when Mr. de Buffon, informed that I had been working on the work of Mr. Tull, brought to me how the translation of Mr. Otter had fallen into his hands, and the work that he had made for correcting it; he added that he had not judged it to be the right moment to make it printed, because the new and useful ideas that the work of Mr. Tull contained, would drown in many vague arguments, and that there reigned everywhere a verbosity that would

[22] Of l'Academie des Belles-Lettres, died in October 1748

certainly hinder it to succeed. I confessed to him that I had had a similar judgment, and that for putting the amateurs of agriculture in reach of profiting from the good ideas of Mr. Tull, I had began an extract of his work. Mr. de Buffon judged that that was the only way that could be taken, had the politeness to give me his translation, so that I could consult it whenever was found an obscurity in that of Mr. Gottfort.

Third edition highly edited, summarized, simplified and prepared for easy use and reference

I continued the work that I had started, and was full of the spirit of the ideas and views of Mr. Tull, I put them in the order that seemed to me proper/suitable; suppressing entirely all that was a stranger to the subject; abridging that which seemed too extensive, detailing the ordinary methods of cultivating the earth, when that seemed to me necessary for making seen the advantages of the new method; adding some experiments for confirming the sentiments of the author; or for warning that it is necessary to be on guard when the principles of Mr. Tull are not well enough established/confirmed. Finally without slavishly following my author, I tried to rend the spirit of the thing under a completely different form.

I must no forget to forewarn the reader that he will not find exhausted material, even in the chapters where I treat one object in particular, like the roots, the leaves, the food of plants, etc. because I tried to report only that which concerned immediately my subject, or that which is necessary for the intelligence of the new system of agriculture.

Despite the additions which belong to me in entirety, and that make a considerable part of the work that I present to the public, I do not believe to have omitted anything that is interesting in the book of Mr. Tull, which nevertheless in English is a little in-folio.

Map/Draught/Summary of the Work: treaty divided into two parts, not three - principles and applications

This treaty is divided into two parts. We expose in the first the principles of the new agriculture, and we give of this some applications to the cultivation of several useful plants; this part contains twenty-one chapters. The second part is intended to describe the instruments which are necessary for cultivating the earth following the new principles.

I will give an idea of the subject of each of these chapters, which will give me the occasion to report certain interesting facts that had escaped he in the composition of the work.

Summary and discussion of work: after experiments are reproduced and the general success of Tullian methods in England is observed, it is found Tullian theory is plausible, but the actual scientific explanation for the success is uncertain

In the first chapter we deal summarily the roots; it is not a question of all the distinctions that the botanists have established; nor of an attentive and delicate examination that a physician can make of the organs that compose them. It suffices for the intelligence of the new cultivation to distinguish the swiveling/turning roots, who sink themselves vertically in the earth, and the creepers, who spread parallel to the surface of the terrain.

The swiveling/turning/creeping (horizontal?) roots serve principally to strengthen the large plants; and the oaks, the walnut trees who have roots of this species, are less subject to being knocked over by the wind than those who do not have them.

We do not deny that the swiveling/turning/creeping (horizontal?) roots pump a very advantageous nourishing juice to the plants; for why do the vine, sanfoin, alfalfa, and so many other flexible plants who hardly run the risk of being knocked over by the wind, throw their roots to so great a depth in the earth, if they do not take up the nourishment from it? But it is certain that the crawling roots who contribute also to strengthen the plants in the earth, are well more suitable than the swivelers/turners to take in the nourishing juice.

It is of observation that the creepers stretch out so much the more that they are more near the surface, that they are more in range of receiving the influences of the sun, the dew, the air, and above all when the repeated tilling/ploughing has opened some passages to the roots, who following our experiments, stretch out and multiply proportionally to the ease that they find to spread. That is what we have proposed to establish in this chapter, and that is what we could have proved with some experiments that we have left out for to not draw out this small work too much.

Without intending to go deeper into that which regards the leaves, the second chapter is destined to the exposition of the different sentiments that divide the authors on their use. Some considered the leaf like the lungs of the plants; they have claimed that they contain reservoirs fill of an elastic air, which from there is distributed in all the parts of the plants; others have believed that the sap was carried in the leaves for to receive there a certain preparation that renders it suitable to then serve as the nourishment/food of all the plant; that which supposed a circulation of the sap which has not yet been well established.

We have assured ourselves by some well made experiments that the leaves inhale the moisture of the rains and the dews; they can then be regarded like some organs that serve to the nutrition of the plants. Finally it is all fairly well proven that the plants perspire very abundantly by their leaves. From which we conclude that they are organs destined to make a secretion very important to the plant economy.

We do not believe we ought to give preference to one of these sentiments: but that all or a part of these uses take place, it remains always to note/certify that the leaves are very useful organs to the vegetation: this is confirmed by several observations that are reported in the second chapter. We could add to them a great many more: but we did not believe we ought to leave out certain ones which are very consistent, and which had escaped us in the composition of our work.

First, if we cut half or two thirds of the leaves of a young tree which is in full sap, we perceive at the end of two or three days that this tree has lost its sap, the bark which before this time detached easily from the wood, has become very adherent. Before the removal of the leaves, we could have made this young tree bud; one day after removing them, it is no longer possible of obtaining a bud; the tree is then weakened by the subtraction of the leaves; that is the consequence that we can pull from the observation that we have just reported.

Second, a willow, a poplar, an elm that we leave to grow without being trimmed, subsists a century without the trunk hollowing; whereas their trunk rots fairly promptly when we form "tadpoles;" the repeated removal of branches and boughs causes them a noticeable harm; that is what the previous experiment evidently proves.

Third, there is only this small couch grass with a fine and slender leaf, that this grass which forms the lovely turf of England, who can stand up to mowed very closely, or to the scythe, or to the herds and flocks, when all the other plants perish.

We can conclude from these experiments that we have jus reported, like of those which are in the second chapter, that we do considerable wrong to sanfoin and to alfalfa when we allow them

to be grazed too often by cattle, and that it is perhaps not as advantageous as we imagine to allow the herds to graze wheat that is too thick/large.

What is the nature of the nourishing juice that the plants pull from the earth? That is a question to which it is very difficult to respond; because on one side the fertility that the different fertilizers give to the earth, seems to prove that the sap is composed of salts, oil, and other substances that chemistry knows how to take out of plants. But the fertility of the sandy earth when not lacking in water, and the success with which we have grown different species of plants in very pure water, are some facts which seem to indicate that the sap is more simple than we had imagined, and that the juices owe their modifications to the organs of the plant.

Mr. Tull thinks that the nourishment of plants is none other than earth reduced into very fine powder; and we have tried in the third chapter to give to this idea all the plausibility to which it is due; however it is probable that the integral substances of the sap, must be dissolvable in water, and the molecules of earth do not seem to have this property. Be that as it may, if we succeed in augmenting the fertility of the earth, we will have reason to console ourselves of the uncertainty that reigns over the nature of the nourishing juice.

The fourth chapter presents a question that is even more difficult; which is also a continuation of that which we have spoken in the preceding chapter. Do all the plants nourish themselves with the same juice that they pull from the earth? Mr. Tull thinks so: but some authors believe that each plant pulls from the earth only that which it finds suitable: from which it follows that an earth can be exhausted for one sort of plant, and not for others. If the farmers remark that barley exhausts the earth more for the following wheat than oats do, that is, some say, because there is more resemblance between the juices of which the barley nourishes itself, and those that belong to wheat, than between the nourishing juices of the oats and those of wheat. Similarly it can be observed that in an earth that has long been occupied by one species that we had planted there succeeds poorly there: but one can be assured more success in replacing this species by very different trees. These facts, and many others that we have reported in the body of the work, seem to not support an identical sap for all plants. But as there are also many of observations that are favorable (to the previously "not supported" idea), we are content to discuss the two ideas without taking any side; the question remains, and it well merits that the amateur physicians of agriculture, take it up as the object of their researches. But that which we believe to have been well enough proven, that is that one of the principle advantages that one can gain in leaving the earth without being sown during the year of fallow land, consists of having enough time for multiplying the plowings/plowed fields as much as is necessary for loosing and lifting up the earth; in a word for disposing the earth to receive the wheat which is the most precious and the most delicate of all the grains. The space of a year is not too much for that; for when it is said that it is necessary to give three or four plowings to the earth to prepare it for wheat, it is evident that one does not procure hardly any advantage, if one leaves too small an interval of time between these plowings; because if by the first plowing we turn over the earth, if we had buried grass, a second plowing given before the grass becomes rotten, before the earth becomes impregnated with the qualities that the sun and the meteors can give it, this second plowing would put the earth back into almost the same state that it was in before the first, would be harmful, or at least little advantageous.

We have begun to make seen the necessity of plowing, we insist on this point in the fifth chapter; because however good is the earth, the plants do not take from it a good advantage, if their roots do not have the liberty to extend for taking the juices from there: an earth too tough forms an insurmountable obstacle; it is necessary then to break it by plowing, and nothing better proves this truth than the great fertility of the kitchen gardens that have been broken up.

We believe we can then state as fact, that the more one divides the molecules of the earth, the more one multiplies the interior pores of the earth, and the more one puts it in a state to supply nourishment to the plants.

The sixth chapter deals with the means that one can employ for making this division; the plowings take place mechanically, calcining by means of the fire, and manure by means of fermentation. But manure distorts/spoils a little the quality of the harvest, and one is not master of procuring from there as much as one needs, whereas one can multiply the plowings as much as one wants, and without fear of altering the quality of the fruits. The manure can well provide some substance to the earth, but by repeated plowings one exposes successively different parts of the earth to the influences of the air, the sun, and the rains, that which makes it suitable for vegetation.

The earth that has remained fallow for a long time, must be plowed with particular precautions from which one is exempt when it is a matter of earth that has been cultivated without interruption, and it is that which we engage to discuss in the seventh chapter, on the unfallowing of the earth. On this occasion we have detailed the method of burning the earth, like I have seen practiced in Brittany, and in other provinces of the kingdom. Mr. Tull disapproves of this practice; it is nonetheless of experience that by this practice one gives to the earth a fertility that lasts several years; and it is well necessary that the farmers are convinced of this, since they commit themselves to a considerable expense in days of labor, and to the consumption of good meals, that in certain countries is not indifferent.

Moreover it is certain that in Normandy they spread lime on their glebes to augment their fertility; and it seems to me to have some parallel between these two methods of fertilizing the earth.

The woods, the moors, and the meadows, must be unfallowed with particular precautions, which we have reported in the same chapter: but it is suitable to add to that which we have said of the ways to provide the flow of the superabundant waters, for which our farmers form deep furrows in their earth that one can compare to small ditches by means of a strong plough that has two knobs or two large broad mould-boards, with a long plough-share, pointed, and situated/figured saddle-back by the superior part. These ploughs do not have a cleaver, because it is not a question of cutting a hardened earth, it is only necessary to open in the ploughed earth a deep and large furrow that serves as a small ditch.

The different types of earth require that we plough them differently, and with different types of ploughs. It seemed to us proper/suitable to give an idea of this in chapter VIII, without undertaking/attempting to describe all the methods of ploughing; those that are common in our own province, would have furnished material for a chapter much lengthier than that which is necessary. We believe however to add to what has already been said, that in the sandy earth when we want to plough in ridges, that is to say, when we want to raise a hill, of a foot and a half or two of width, between two large furrows, we plough sometimes the earth to be flat, we seed it, and we bury the seeds with a harrow; then we form to two feet from one another deep furrows with a plow made expressly for this purpose, that we call "à billonner" (roughly, a ridge-maker), it has no coulter, but a long and straight plow-share with two large broad mould-boards of the side of the handle of the plow, and indented below, of the type that this plow makes by its point a corner that opens the earth, the middle of the mould-boards turns the earth over on the sides, and their (the mould-boards') widest and most indented extremity smoothes this earth, that which gives the ridge the very regular form of a hill: but this method of ploughing is only applicable in sand; such a plow will homogenize clay earth, in this type of earth the plough-share would even have difficulty in opening a passage.

All the different ploughings of which we have discussed in the chapter, can be done equally by horses, mules, or oxen; each can conform itself to the use of its country, though it is desired to one

makes more frequent usage of oxen, as we can thus spare the horses, and thus multiply an animal which increases in price when it becomes older.

This detail on the different methods of ploughing the earth, was necessary for the better understanding of the advantages of the new farming, of which the fundamental principles have been reported in the ninth chapter. It boils down to better preparing the earth that we must seed, to chose good seed, that we must not scatter it, like we would ordinarily, but that it is necessary to distribute it suitably. Finally when the plants have emerged from the earth, we must not abandon them to themselves, it is necessary to cultivate them from time to time like we do with the kitchen garden plants: if these (the kitchen garden plants) succeed poorly when they are neglected of being cultivated, why would it not be the same of the grains which make up an considerable part of our revenue? The habitants of several provinces in France[23] and in England cultivate by hand their wheat as it grows; and they are compensated at the time of harvest of a job that is just as tiresome. How many of these ploughings would be more advantageous if they had been made with less expense? We obtain this in following the method of Mr. Tull, which we will find amply detailed in chapter 10. Here follows a general idea.

It is first necessary to plough the earth to eight or ten inches depth; and Mr. Tull proposes for this to use a strong plough which has four cleavers and a large plough-share; when the earth is well prepared it is necessary to sow it; but instead of throwing a lot of seed by hand, and without precaution, it must be distributed in rows, sufficiently remote from one another, and the grains placed there at a depth and at proper distances; this we can do promptly and with one operation with a seed drill invented by Mr. Tull. Finally as soon as the plants grow, it is necessary to plough the earth that we had left barren between the rows; this can be done with a light plough which has no cog/wheel, and at the middle of which we can plough very close to the rows without damaging the grain; for myself I use a small plough that I have made more ploughing the seedlings of wood/trees, as I have explained elsewhere. The description of this plough will be found at the end of this volume.

Is it necessary to put more grain in "fat" earth than in poor earth, or the opposite? That is a question that has long divided authors of agriculture. Those who maintain the first sentiment say that "fat" earth are in a state to nourish a greater number of plants: but the others fall upon two strong reasons; wheat better withstands the rigors of winter in good earth than in poor earth; and what's more, that wheat spouts and forms secondary leaves much more in good, rich earth than in "light" earth. Since following the new methods we must give consideration to the vigor of the plants for seeding the grains more or less separated from one another, it follows that we must put less grain in the earth which furnishes the most vigorous plants. But in whatever type of soil it may be, we use much less seed in following Mr. Tull's method than we would ordinarily.

If a farmer thus decreased his seed without changing his habits/customs, he would run the risk of not harvesting anything; because as we prove in the eleventh chapter, the weeds get the upper hand of the wheat: but the ploughing that Mr. Tull advises while the wheat is in the earth, remedies this inconvenient and destructive problem of most of these harmful plants.

[23] The earth of Haut-Gratinois retains water, which necessitates the farmers to plough by plant beds, and to only seed the most elevated of the plant beds, in such a way that more than half of the earth remains barren until near the middle of spring; when the waters have retired and the earth has dried out, they plough by hand this earth which has not been seeded, and they sow there turnips, broad beans, peas, etc their purpose restricted by the reality of making a profit of all their land. But it is certain that the grain that had been sown on the middle of the plant beds, derives a considerable advantage from these plowings.

The choice of seeds which is the subject of the twelfth chapter is worthy of attention. First, with regard to wheat, the newer is preferred to the older, because nearly all the grain grows, we can employ that of the preceding year, although several seeds remain useless: but those of the third year ordinarily come to nothing, either because the shoots are altered, or because the insects have destroyed a part.

Second, we find in several works of agriculture, the recipes that we often use for procuring the development of shoots, in putting the grains to soak in certain liqueurs.

Our farmers soak their wheat in lime water, and they claim that the lime prevents their wheat from becoming black and charred. I am not in a position to decide positively on this point, nor on the excellence of the liqueurs of which I have spoken of earlier, although I had made several years ago some experiments which seem to me proper to be made known that which reasonably came of these (experiments); I am actually making some new experiments, and if these teach me something satisfactory, I will not neglect to inform the public of it.

Third, it is generally thought to be advantageous to change seed from time to time, it has also seemed to me that experimentation justifies this practice: but most authors think that it is best to seed the earth with grain which had been gathered in more poor land than that which will be cultivated with it. Mr. Tull believes instead that it is necessary to take seed from the best land: this question is discussed and not decided in the body of the work: but the most common practice of our farmers is to pull seed from the best earth, or again to buy by preference the wheat of the gleaners; as it has been gathered ear by ear, it is very pure of bad grain, and the grains are ordinarily of good quality; this conforms to the feelings of Mr. Tull.

Finally there are some fairly good authors, who believe that seeds sometimes change species: that the wheat, for example, degenerates to rye, vetch or barley. They (the authors) state that sometimes one finds seeds of rye, vetch, or barley in the ears of wheat. I have uselessly searched for seeds of rye or vetch in the ears of wheat; because one must not take for rye or vetch the small, dark seeds which are found at the tip of the ears, and which ordinarily do not grow.

Mr. le Chevalier de Laumoi my neighbor and relative, wanted to confirm/establish with the greatest exactitude that which regards wheat, and this fact merits consideration, because one does not find this seed to buy without it being mixed with a little barley; similarly it is rare to find wheat absolutely free of rye.

He had sorted seed by seed enough wheat for seeding an acre of earth; and he had sown another acre with non-sorted seed, of the kind that is found at the market; he was not surprised at the time of harvest to find barley in this acre, because he had sown some, he must harvest some: but in the other where he was sure to have not sown any barley, he did not find one ear, and he had carefully examined the ears, he did not find there a seed of barley. If then we find a little rye or barley in the wheat, that is because these seeds are sown in the same season, in similarly prepared earth, they are reaped at the same time, we shut them in the same barns; this is more than necessary for producing the mixture that we observe; almost always the marvelous disappears when one examines the facts with enough attention.

After having sufficiently detailed the general principles which serve as the basis of the new methods, it is suitable to make applications to the particular cultivation of some plants, we have chosen for example the turnips, wheat, sanfoin and alfalfa.

In the thirteenth chapter we describe the ordinary cultivation of turnips, and we explain in the fourteenth chapter the cultivation of this plant following the principles of Mr. Tull. We have similarly employed two chapters, the fifteenth and sixteenth, to explaining the method of cultivation of wheat following the old methods, and following the new principles.

But as wheat is the most precious of all the seeds, we are more extensive on hat which applies to its cultivation, and we have employed the seventeenth and eighteenth chapters for detailing the illnesses of wheat, which can be prevented in part by following the principles of Mr. Tull.

Before abandoning wheat, it is suitable to report an experiment that I have made in brief, to compare the two methods of cultivation.

I had ploughed by spade a parallelogram of earth ABCD (Pl. III [note-I don't have it anymore]). I had seeded a part AEFD in the ordinary way, and the other by rows similar to GHIK, which were distant from one another by about four feet, and the seeds were in the rows at six inches from one another. This little field was seeded near the end of December. In the month of March following I ploughed by spade the earth included between the rows; when the wheat of the rows sowed its shafts, I ploughed a second time; and finally a third time a little after it began flowering.

When this wheat had matured, all the seeds in the middle of square AEFD, had only produced one, two, three, four, sometimes five, and rarely six shafts; whereas the seeds of the rows had produced from eighteen to forty shafts; and the ears of the rows were much longer and more full of seeds than those of the mass/clump/bed: but the birds devoured the seeds before they matured, we cannot compare the products.

We notice (point out?) expressly that it is necessary to compare the product of the seeds that had been sown in the middle of the mass/clump/bed, with the product of the seeds of the rows, because the circumference of the mass/clump/bed is almost in the same case as the rows. And its for this reason that along the vines and roads, the wheat is nicer looking than in the middle of a mass/clump/bed/field.

The nineteenth and twentieth chapters are intended to show/explain the cultivation of sanfoin and of alfalfa.

We have much insisted in these chapters on the precautions that one must take for preserving the seed of sanfoin, because Mr. Tull believes it necessary; nevertheless, our farmers preserve this seed very well, by spreading it somewhat thinly in a granary, and in moving it from time to time.

We have made in the twenty-first chapter which ends the first part of our work, a parallel of the old and new cultivation which makes clear the advantages that one can expect of the method that we propose.

We only evaluated the products of our land which were reputed to be good, or four, five, or at most six for one; that is to say, that a farmer who sows one hundred septiers of wheat, could hardly hope for a harvest of five to six hundred septiers; and Columella did not estimate that his land in Italy produced more. It is true that there are certain pieces of land that give ten for one: but when we speak of the product of the land, it is an average estimation taken on all the land which makes up a large farm.

Pline (the Roman Historian, "Pliny") nevertheless speaks of the great fertility of certain lands which yield one hundred or one hundred fifty for one. It would not be difficult to give examples of an even greater fertility, since when cultivating seeds of wheat in a kitchen garden, it is common to see them produce each forty and fifty ears; and each ear to contain forty or fifty seeds, that which makes sixteen hundred, or two thousand, or two thousand five hundred seeds for one. However if it is possible to reach on a large scale this fertility, it is surely in following the principles of Mr. Tull, since his cultivation is similar to that which we give to our kitchen garden plants; but then/with that for persuading others to gather proof of this, I do not claim/aspire to excuse myself from it; and I have already make the preparations for doing this ("en grand" - ?.. "on a large scale?").

In favor of further trials

That which we have said in favor of the new method of cultivating the earth, seems sufficient for engaging/persuading amateurs of agriculture to try it; and following the success of their first trials, they can with knowledge of reason/motive capitalize on this method with a greater or lesser portion of their property. Because when one can be well assured of thus increasing the harvest of wheat, he can have solid reasons which persuade him to one use the new method of cultivating the earth, for only a portion of the property. I do not attempt to detail here all the reasons, it suffices for me to only report several which I will present under the form of objections.

Several objections and responses: 1) O: when all land is in wheat, horses have no oats to eat and fowl have no barley; R: wheat can be sold to buy oats and barley from those with land more suited for oats and barley 2) O: Tull does not allow for grazing livestock, and no livestock will be raised; R: Tull does advocate raising animal feeds and penning and feeding the animals, which do better under this system than under grazing

First objection. Following the new method all the land is perpetually seeded in wheat, the farmer does not harvest any oats for feed for his horses, nor barley for fattening his fowl.

Response. This objection is strong, nevertheless I pray that we bring attention to the fact that land that is better for producing wheat, is rarely very good for oats, and that those lands that are the best for producing these lesser grains, usually give little wheat. For example, the land of Beausse usually produced more wheat, and less oats than the land of Haut-Gratinois.

This principle once established, it seems to me that it would be for the general good that we seed all the land of Beausse in wheat, and all the land of Gratinois in oats; the workers of one and the other province will find there an advantage, and the result of a larger harvest will be of advantage to the public. But without changing province I have often remarked that a park of the land of a large farm is very good for wheat, while another is only good for lesser seeds. In this case a landowner would be the benefit of his farmer in permitting him to disarrange/displace the (??? Solles/folles – No translations to be found) to employ them for producing the type of seed that he knows by experience grows better there.

We could apply to other lesser seeds that which I have said regarding oats; therefore I believe to have responded to the first objection.

Second objection. Livestock is a lucrative object for the farmer; necessary to the public, and what is more, advantageous to the land due to the manure that fertilizes it, which is also done under the principles of Mr. Tull. In following the new method, all the land is cultivated and continually occupied by crops; of the sort that there are neither stubble/thatch, nor fallow to serve as pasture to the flocks and to the livestock; thus no more livestock, no more use of forage, no more manure, no more fertilizer for the land, etc.

Response. I believe that this objection did not escape Mr. Tull, and that he accounted for designating a part of the land for raising radishes, turnips, and other forages that the English call artificial pasture, which according to him provides for the needs of livestock. That which is certain is that Mr. Tull states in several places in his work that he thinks little of ordinary pasture, or of natural meadows, and that by means of a small quantity of earth that he carefully cultivated in artificial pasture, he keeps his livestock in better condition that his neighbors.

We would not be shocked by this, if we realize that one acre of good meadow produces more grass than six acres of fallow ground or of stubble/thatch, and that one acre of alfalfa produces more

grass than six acres of good meadow; that which makes realized that the product of a good acre of alfalfa surpasses that of thirty or thirty-six acres of fallow ground or stubble/thatch; if this is the case, should we not agree with Mr. Tull that it is more advantageous to keep a small part of the land for the subsistence of livestock, than to poorly cultivate all in prejudice of the harvest, which is an essential object.

Moreover how many private individuals are there in the kingdom of which the estate/property/land/farm is limited to eight, ten, or twelve acres of land that they rent to farm from their neighbor farmers; they have neither horses nor livestock, are infinitely interested in increasing their wheat harvest, and they would find themselves blessed/happy if in practicing the new methods of cultivation they obtain from twelve acres a harvest as large as eighteen or twenty had they continued in following the ancient methods.

Seed drill construction instructions especially difficult to translate; to this has been added descriptions of rolling harrows and French light plows

The five chapters of the second part, are entirely intended for the description of ploughs, seeders, and other instruments that Mr. Tull has created for cultivating the earth. We admit/own that the description of the seeders is long, and nevertheless/yet/still sometimes obscure. We have however given all possible care to well translate the English; we have also had the chapters reviewed by different people who know English very well.

We have here added a rolling harrow, of which we have spoken in the first part, and a light plough, chapter six, very simple, that we use for cultivation our seed-plots of wood, and which can be substituted for the light plough of Mr. Tull.

Added discussion of a Spanish seeder by Dom Joseph Lucatello, invented 100 years previously

Chapter seven is the translation of a passage of the Summary of Philosophical Transactions by Baddam, vol.I, p. 248, which reports the description and the use of a Spanish seeder invented by Dom Joseph Lucatello, of which is discussed in the Philosophical Transactions No. 60. p. 1056. It is equitable/just/correct to make mention of a method of cultivating the earth, which has merited applause, and which for the essential things has much connection with that of Mr. Tull. And a Spaniard worthy of trust has assured me that this method which was invented nearly one hundred years ago, is still practiced in several provinces of Spain.[24]

We has announced in the last volumes of the Memoirs (Ed note: my guess of the abbreviation "Mem.") of the Academy (Ed Note: Royal Academy of Sciences of which he was a member?), that we would be making experiments on the preservation of wheat. It may be well to warn/notify/tell that they are being followed with all the exactness possible; and we hope to soon be in a position to share them with the public.

This will make in some way (ie This concludes) the second part of the work; and we have spared neither carefulness nor cost so that there remains nothing more to desire on a subject so advantageous to the public.

[24] This seeder is different from and inferior to the seed drill in many aspects and is discussed in subsequent chapters. It is not a drill, and thus has few of the advantages of Tull's invention. –A.B. & M.C.

THE FOURTH EDITION BY WILLIAM COBBETT

P R E F A C E

About William Cobbett: he desired to publish the Horse Hoeing Husbandry to save his Democracy and Republic from corruption, to reduce the oppression of the poor, to uphold human rights for men and women, to allow financial independence to the farmers and to all people, and to vindicate Tull against the lies made by their opponents who sought the continued corruption of Democracies and Republics, the suppression of rights, the oppression of the poor and the enslavement of free people



William Cobbett published the Horse Hoeing Husbandry in 1822 and again in 1829 during a period of great activity (he would come to hold the parliamentary seat of Oldham in England in 1832 simultaneous to his victory in obtaining passage of the anti-corruption Reform Act of 1832). He was born to a tavern owner (the Cobbetts ran The Jolly Farmer), who taught him to read and write.

When he left for London in 1783 to become a clerk for Grey's Inn he was dissatisfied and joined the British Army in 1784 where, in the great amounts of free time the soldiers enjoyed, he taught himself grammar and read many, many books. Posted to New Brunswick, he rose to the rank of Sergeant Major before being discharged in 1791. Upon returning to England, he married Anne Reid, whom he met in Canada.

He was disgusted at the corruption of his officers and, after gathering evidence against them and finding that the law would not prosecute the crime (the charges kept getting sidetracked), he found himself a target of legal action and fled to France in 1792 to avoid imprisonment. Finding France in civil disorder from the Revolution, he sought safety in the new United States, "anxious to become a citizen of a Free State."

In Philadelphia, he earned money teaching English to Frenchmen and by providing translational services. Yet he quickly became disillusioned with the corruption and hypocrisy in America: there was no true equality, women and other minors were denied emancipation, violence was extolled and democracy denied. He wrote many pamphlets and articles under the name "Peter Porcupine" that, naturally, upset the American governmental leaders.

Benjamin Rush, a Founding Father of the United States, found and accused Cobbett of treasonous pro-British propaganda and Cobbett was forced to flee to England in 1800, where he was warmly welcomed. He refused compensation for his propaganda efforts in the United States – it was not done to please the English. Two years later he began the journal, *the Weekly Political Register*, a conservative newspaper that focused on debates in Parliament, the need for political reform (especially the reorganization of Burroughs, some of which yielded unfair powers by having exceedingly low populations (some had only a few dozen people). When he ran for Parliament, he refused to bribe these small boroughs and lost.

He finally went to prison in 1810 for libel and was sent to the notorious Newgate Prison. While there, he wrote his *Paper against Gold*, of which he is so proud in his Introduction to the Fourth Edition and many other pamphlets. His release was celebrated by a dinner with 600 supporters of political reform.

High taxes on newspapers limited their circulation, but Cobbett retained 1,000 subscribers. In 1817 he again feared arrest and fled (again) to the United States where, on Long Island, he wrote books on grammar, farmed, and supervised the continued publication of the *Register* in England. In 1819 he returned to England (after the Battle of Peterloo, where British soldiers attacked an 80,000-strong unarmed civilian protest demanding political reform of parliamentary representation). He was charged with libel and threatened with arrest several more times, running again for Parliament and losing again. It was at this time he republished Jethro Tull.

While not Catholic, he took up the causes of Catholic emancipation and religious tolerance. He encouraged rural riots and was charged with sedition. He lost Parliamentary elections until the Reform Act of 1832 was passed and he was allowed a fair fight, which he then won.

Just as those who discontented with civilization and peace are drawn to hate the works of Jethro Tull, so are those who dearly love those fine fruits of farming, who love the great good world, drawn to its support. Cobbett, who dedicated his life to political reform, is a natural choice for an editor of the Horse Hoeing Husbandry, and Tull is fortunate that Cobbett lent his expertise as a printer to him. —A.B. & M.C.

History of the Horse Hoeing Husbandry: written in stages, assembled by Cobbett

THERE are some circumstances, connected with the history and division of the work of Mr. TULL, which it will be necessary for me to explain; and I think it may be useful to speak of some experiments, of recent date which have been made by myself and others, and which were made in consequence of reading the work here presented to the public.

As to the former, the work was written and published by Mr. TULL in several distinct pieces, and at several different times. He never published a new and complete edition, in one volume; but, took the several parts, bound them up in one volume, and, in each part or pamphlet, made continual references to what had been published before. As the years passed away, and as his experience taught him, he altered his opinions, and, of course, his method of proceeding.

The publication of the nineteen Chapters of his work were, in some years afterwards, followed by a mass of Notes, nearly, if not quite, equal in bulk to the Chapters themselves. So necessary was it, that these should be read along with the Chapters, that he gave a particular direction at the head of this collection of Notes, that the reader should, before he read the Chapters, go over the Notes, see what page, line, and sentence each referred to; then mark with a pen, in the Chapters, the places at which the Notes were to come in; and then begin to read the work, and to be sure to read in the Notes. In short, this collection of Notes was to make part of the Chapters, and they were written in a way to be brought into their several places, and there make part of the Chapters themselves, which, indeed, were altogether imperfect without them.

This being the case, I have, in this edition, done what the author would have done, if he had lived to send a new edition to the press. I have brought all these Notes, or parts of Text subsequently written, and have introduced them to the text at their proper places; which will be found to be a very useful typographical improvement. Notes are always disagreeable. They are always to be avoided if possible; but a book, half text and half notes, the former incomplete, and even erroneous, without the latter, was an inconvenient thing indeed; and such as it was absolutely necessary to get rid of. Some editors of TULL of about forty years ago, have gone a short way indeed to work: they have wholly omitted this body of Notes; or, rather, in the author's view of the matter, this large part of the text; and have, thus, presented to the reader a thing which is really not the work of TULL.

The introducing of these Notes, in the manner just described, produces, here and there, a sort of disjointedness in the matter. For, though the author was writing parts to come in, his connecting phrases are not, everywhere, so naturally applicable as they might have been. This, however, is merely an awkwardness of manner, and that only in a very few instances; and, in no instance, has it the smallest tendency to mar the meaning.

Tull's inventions so widely used that inclusion of detailed descriptions unnecessary

One part of the work of Mr. TULL treats of the making and the using of drills and ploughs and horse-hoes. He was the inventor of the first drill. Of course, he has numerous and very particular and minute written descriptions and instructions relative to the mechanical matters, beside a great number of engravings. These, though matter of curiosity, can be of no use now-a-days, when the making and using of instruments of this sort are brought to such perfection; and as it was an useful, and not a curious, book that I was desirous to present to the public, I have, agreeably to my Prospectus, wholly omitted this part of the work. The reader will, however, find now and then a passage, in which this is omitted part of the work is referred to; but, as he will have a knowledge of

the ploughs and drills of the present day, this circumstance cannot be productive of any misconception or inconvenience.

About Jethro Tull: Tull was a lawyer

The author was a Lawyer, and his having learned the Latin language, induced him, like most others who have been taught what they call "the learned languages," to use the Latin, and sometimes the Greek words, when quoting from Virgil and others. I have thought it best to retain the words, thus used, in those languages. They are, in general, translated by the author; and, in the few cases where they are not, no inconvenience can arise from the omission. The Chapter on the Virgilian Husbandry is very curious. In it we clearly see, that we have all our old agricultural notions and practice from the Romans; and, whoever has observed much of the agriculture in France, will know, that, there, the Husbandry is, to this day, very nearly the same that it was in Italy in the time of Virgil.

Addenda and notes on the preface included after the work, as are refutations to the unreasonable attacks by Equivocus with a footnote on how the Horse Hoeing Husbandry, and the authors cited in its 5th Edition, have been similarly attacked with the intent to disclaim, defame, disdain, dismiss and obscure those men and women and their works

Besides the mass of Notes, before-mentioned, there was an Addition, which the author calls an Addenda to his Husbandry. This was a very important part; and it has, therefore, been put in its proper place.

Last of all came "Notes on the Preface," which are here, as in the author's collection, placed after the work. They are very necessary to be read, relating as they do, to many essential matters, omitted in the Preface; and, especially as they speak of a Society of Writers, who were anonymous, and whom, therefore, as well as on account of the doctrine of equivocal generation of plants, which they held, he calls "the Equivocal Society," and, sometimes, for brevity's sake "EQUIVOCUS." This Society published, as it appears, a periodical work on Agriculture; and it also appears, that they contended against the doctrines of Mr. TULL, and treated him with great severity and brutality. They were, in their day, in Agriculture, what the greater part of our Reviewers now are in Politics. They had no names, any more than our critical sages have; and, it is not improbable, that some future editor of Cobbett's Essays on Paper-Money, may have to perform for the Edinburgh and Quarterly conjurers the office which I am now performing for TULL'S "Equivocal Society," who and whose works are now, what Walter and Stoddart and Old Times and New Times will be fifty or sixty years hence; that is to say, wholly unremembered except in the pages of those works, which they have vainly endeavoured to suppress by their calumnies on the authors.[25]

[25] Though it is unfortunate that many of Equivocus's lies have become to stand for Tull's true words, it is no less hideous a thing that no one remembers who Equivocus was. In fact, the success of the misinformation perpetrated by Equivocus becomes more grotesque when it is understood that now the misconceptions have been held as fact so long as to require sometimes excessive evidence to refute, and sometimes cannot be refuted at all. While finishing this work, we encountered a farmer who publically disparaged Tullian farming and its legacy until we introduced the actual Horse Hoeing Husbandry to him, at which point, shocked at how he had been misled, he felt some of the

It appears to me, that, after the Author's Preface, the Notes to the Preface ought to be read; for though, being written after the work, they allude and refer to many things rather out of place; still, these Notes are necessary to give the reader a fair view of the Author's situation at the time of writing the work, and of his objects in writing it: and we never enter on the reading of a work with so much advantage as when we are thus prepared.

Recent experiments confirm Tull's method

As to the recent experiments, of which I am about to speak, it should be observed here, generally, that it is the principles of Mr. TULL, and not the whole of his particular practice, that the scientific farmer and gardener will turn to account. Mr. TULL'S main principle is this, that Tillage will supply the place of manure; and his own experience shows, that, a good crop of wheat, for any number of years, may be grown, every year, upon the same land, without any manure, from first to

violation Tull undoubtedly did. That some of these violations are undertaken even today by esteemed Professors of renowned and reputable Universities is astonishing.

We remark now Kevin Gilmartin, of the California Institute of Technology in his article on *Romanticism and Conspiracy William Cobbett and the Politics of System*, part of *Print Politics: The Press and Radical Opposition in Early Nineteenth-Century England* (1996). Gilmartin puzzles at how "Given William Cobbett's extraordinarily single-minded obsession with an 'all-corrupting and all-degrading system' of political oppression and economic injustice that had, in his view, dominated British life at least since William Pitt's direction of the wars against Revolutionary France, and given his own assurance that he had devoted his career to analyzing 'all the grounds, all the causes, all effects, all the various workings of the thing; all the whole history and mystery of this grand delusion' (Register 36 [1820], 684-86), it is curious that some of his most incisive critics agree on nothing more than that he was not a systematic writer."

Regardless of the merit of Cobbett's ideals, his critics demonstrate cowardice by not debating with them. Cobbett's greatest critics, instead of debating his arguments, sought to declaim, defame, disdain, dismiss and obscure the man and his works. This cowardice, similar to Equivocus's, is a typical tactic of those who oppose the legacy of enlightened science's pursuit of Truth Justice. Truth and Justice being all victorious, those who would oppose it must fail, and so they seek to avoid confrontation entirely.

Many of the authors and scientists that this 5th Edition leans upon have been shamefully treated in similar ways. Charles Darwin (whose frequent and repeated abuse requires little recall here), Jacques Cousteau (whose opponents had to invent social and scientific sins when they found none), Dr. John Kellogg (who was dismissed as bizarre and worse), and even the USDA and UNFAO (whose leadership is regularly accused of various corruption and suspect science). Why, even Dr. James Lovelock, many of whose mathematical prophecies have come to pass within his lifetime, is debased as a fraud. Should our own names – or the names of any of the respectable men and women who join with us in advancing agriculture – be added to this glorious list of candid witnesses, there is little reason to fear for honor's sake. Regardless of what opponents may say about a man or woman's work, the work can be found to either stand upon its own merits or not through tests undertaken by the reader.

Jethro Tull's method works, and it works so well because he anticipated these attacks, and sought to demonstrate how the reader could undertake their own trials to see the shocking results for themselves. His honor, the honor of all those witnesses we call upon in this volume, and our own are safe if tested by a fair trial before an unbiased jury. –A.B. & M.C.

last. The recent experiments that I have to mention confirm this; but, there is a difficulty in the case of wheat, mentioned by Mr. TULL himself, and which my experience also confirms.

Experiments by Cobbett prove Tullian superiority

It is naturally asked: "If perpetual crops of wheat can be produced on the same land without manure, why is it not done?" The answer to this question will be found in the following account of experiments.

Experiment in Spring-Wheat, in 1813.—On the 5th of April I sowed a land broad-cast, all across a field, which land contained thirteen rod or perch of ground. The land was in a very good state and very suitable to the crop. On each side of this land, and close to it, were made three ridges across the field at three feet asunder; and on these ridges was sown wheat, of the same sort, in a single drill, or row, upon the top of each ridge. So that there were two thirteen rods of this Tullian wheat. The broad-cast wheat was weeded and kept in very good order; and the Tullian was very nicely ploughed between and kept clear from weeds in the rows themselves. Many persons saw this wheat while growing; and though all were struck with the superior strength of straw and length and size of ear in the Tullian wheat, it appeared to everyone impossible that a land, nine feet wide, having only three rows of wheat on it, should bear as much as a like quantity of land covered all over with wheat plants. One of the gentlemen who saw the wheat, while growing, was Mr. MISSING, the Barrister, of Posbrook, about seven miles from Botley. In order to "try the question," as the lawyers call it, he and I made a bet as to comparative quantity; he bet on the broad-cast, and I upon the three rows.

The whole was reaped on the 16th of August, and housed on the 20th of the same month. In a little while after, it was, in the presence of Mr. MISSING, thrashed out; the broad-cast by itself, and the two sets of three rows together. The two parcels were then winnowed. Then the Tullian parcel was divided in two; and the result was as follows

	Bushels	Gallons
Clean wheat on Thirteen Perches, in the Tullian manner, single rows on three-feet ridges...	2.00	5.75
Clean wheat on Thirteen perches, Broad-cast.....	2.00	7.50

The first was at the rate of 33 bushels 6 gallons to the acre; the latter at the rate of 36 bushels half a gallon to the acre. I proposed that, in estimating the crop, we should take the seed into view, and that my side should have added to it a quantity equal to the difference in the quantity of seed that the broad-cast had demanded more than the Tullian. And, though my antagonist was by no means prepared to admit of any such interpretation of the terms of the bet, the reader will see, that, in estimating the clear relative produce, the seed must be taken into view. Now, then, the broad-cast was sown at the rate of three bushels to the acre; the Tullian at the rate of five gallons to the acre. The accounts therefore stand thus:

		Bushels	Gallons
BROAD-CAST.	Produce.....	36.00	0.50
	Deduct Seed.....	‹3.00›	0.00
	Clear Crop:	33.00	0.50

TULLIAN.

Produce.....	33.00	6.00
Deduct Seed.....	0.00	<5.00>
Clear Crop:	33.00	1.00

Thus, then, the clear produce is rather greater in the Tullian than in the other.

Besides this experiment, I made another upon a part of one of the rows. I took ten feet in length of one of the rows, and thinned out the plants so as to leave only twelve plants in a foot in length. The produce of these ten feet was 1.50 pint within a mere trifle; and it weighed 1lb, 5oz avoirdupois. Another ten feet, adjoining the former ten feet, but not thinned out, produced not so much by a wine-glass full; but it weighed precisely the same, owing to the unripeness of the former, some of the ears of which were quite green when cut. Now observe; this thinned wheat, which would not require more than about a gallon and a quarter of seed to an acre, produced at a rate of thirty-one bushels and nearly a half to the acre; and the wheat (Spring wheat too) weighed at the rate of 56lbs to the Winchester bushel. The weight of the straw, when thrashed, on the ten feet, was 2lbs, 7oz and, on an acre, it would have been 1ton, 11cwt, 2qrs, and 21lbs.

It must be observed, however, that the year 1813 was the finest year for wheat within the memory of man. If the summer had been cold, and the harvest backward, the result, in the above case, would have been very different. The reader will note well what I have said about the unripeness of the ears on the ten feet of thinned wheat. Here the wheat was backwarder than in the rest of the rows which were not thinned; and, throughout the whole of the rows, the wheat was backwarder than in the broad-cast. This is the obstacle, and the only obstacle, to growing Tullian wheat. The tillage makes the plants keep on growing to a much later period than when they stand thickly all over the ground, and have no tillage while growing. This late growth, and the juiciness of the stalks and leaves, expose the plants to that sort of blight, which makes the straw speckled, and sometimes gives it a dark hue all over. And whenever this blight lays hold, the grain is thin and light. The Tullian grains are much larger than those of the broad-cast; but, if the blight lay hold, they are not so heavy, nor anything like it. In hot countries, where this blight is unknown, the Tullian wheat would always exceed the broad-cast; but, in this chilly and backward climate, you must, on an average of years, expect this blight unless you so very early. This I found to be the case. My land did not permit me to sow early; and, though I had, in 1814, on a five-acre field, four quarters to the acre of white Essex wheat, sown on four feet ridges, a single row upon a ridge, I found so much blight generally, that I was obliged to discontinue the system, as to wheat, though, with regard to Swedish Turnips (I never raised any other) I found it so excellent.

If you can sow your wheat in August, five times out of six you may escape the blight in the straw. But even then you must not sow too thin; always bearing in mind, that the thinner the plants stand, the later the wheat is in getting ripe; and the greater the chance of blight. It is to be observed that Mr. TULL'S was a high-country farm. I went to see it last fall. It is on a bottom of chalk. It is Saint-Foin land. The sowing always takes place early; and this by no means applies to low, deep, rich, or stiff lands; though, we are now about to see that the system, even as to wheat, may be applied to strong lands.

Experience of other farmers using the Tullian system

When in Herefordshire, last fall, I heard of a gentleman, Mr. BEAMAN, who had, for many years, raised wheat in the Tullian manner. I had not time to wait upon that gentleman myself; but, I put on paper certain questions, which I requested Mr. PALMER, of Bollitree Castle, to put to Mr. BEAMAN, and then to send the questions back to me, together with the answers. This was done by Mr. PALMER, in the following words:

How many years has Mr. Beaman grown Tullian wheat upon any one field, without the intervention of other crops?—Answer. Six Years.

Has he manured for it?—Ans. No.

What has been the width of the ridges?—Ans. Began at twenty-seven inches, then at four feet and a half, and, lastly, six feet.

What have been the number of rows on each ridge?—Ans. One row on twenty-seven inches, two rows on four feet and a half, and three rows on six feet.

What is the season of sowing?—Ans. The earlier the better; should be up before Michaelmas.

How many ploughings, and the seasons of the ploughings?—Ans. The oftener the better; cannot plough too much, nor too near at the first ploughings.

What is the quantity of seed to an acre?—Ans. From half a peck to two bushels; but this must depend on the soil, and upon the season of the drilling.

What is the expense of the crops?—Ans. Twenty-three bushels to an acre.

Does it blight more than other wheat?—Ans. Thinks it does.

Please to get samples from of as many years as possible.—The samples got are of the years 1820 and 1821.—N. B. Very good wheat. I guess it to weigh 57lbs or 58lbs a bushel.

What sorts of wheat has he drilled?—Ans. He has drilled all sorts; prefers a short stiff straw.

What is the quantity of the straw?—Ans. About a load and a half to an acre.

To the above Mr. PALMER added, that Mr. BEAMAN calls his land, "a marly clay." "The top-soil," says Mr. Palmer, "is a stiff, dark-coloured loam, upon a marl and clay bottom." Mr. BEAMAN thinks a single plant in about three inches would grow the greatest crop of wheat; but, then, the wheat should be up in August.

I am very much pleased with this information from Mr. BEAMAN; because there is the thing now to be seen! Mr. TULL continued his wheat crops to the harvesting of the twelfth upon the same land without manure; and, when he concluded his work, he had, as he informs us in a Memorandum, the thirteenth crop coming on, likely to be very good. Mr. BEAMAN had had six crops, and the average of his crops had been twenty-three bushels to the acre, which is more than Arthur Young allows as the average of the Kingdom. However, is there any farmer in England (no matter what his land may be) who would not be glad to get twenty-three bushels of wheat from an acre, year after year, without manure and with so little expense as that of four or five horse-hoeings and two shillings an acre hand-hoeing? The blight is the only obstacle; but, perhaps Lammas wheat sown in August, or spring (bearded) wheat sown early in March, would, five times out of six, escape the blight; and, unquestionably, a field of Tullian wheat in ear, with the ridges straight and the land clean, is the most beautiful thing in the vegetable world. It is not grand like the Indian corn; but it is even more beautiful than that. After three or four crops, there is very little trouble from weeds or grass. The land is prepared for any crop; and it is bearing a good crop, while the preparation is going on.

Beside the early sowing, care must be taken not to sow too thin. By thick sowing along the drills, you get the plants to stave on one another a little, and the wheat ripens at an earlier period. Mr. TULL, in his Memorandum, says, that he put one row on a single ridge in part of a field, the last year of his farming; but missed ascertaining the effect owing to his being ill, and to the hurry of the harvest. I am inclined to think, that it would not have answered; for the fault always is, that the plants keep on growing to too late a season; and the nearer you go to them with the plough, the more gross they will be, and the later they will continue to grow. And, we see, that Mr. BEAMAN began with one row on a ridge; but that he has now come to three rows.

Praise for Tullian agriculture and for Jethro Tull

This grossness produced by the tillage does, however, fully show the truth of the grand principle of TULL; namely, that tillage, and tillage alone, will create and supply the food of plants, and will, in many cases, render manure wholly unnecessary. In diverse cases the Tullian wheat culture may be of use; but it is in the cultivation of cattle-food crops that its great excellence is found. The effects of the tillage while these crops are growing, we can all see plainly enough by looking at the crops themselves; and by the work before us we are taught the causes of those effects. It is not the mere putting of plants in rows that was taught by Mr. TULL; but the reasons for doing this; and, in the stating go those reasons, he has developed all the great principles of vegetation. He was, indeed, the inventor of the first drilling machine; but that which entitles him to our admiration and gratitude, is, that he discovered and explained to us the reasons for inventing that first drilling machine.

It is impossible for any man of just sentiment to read the work of Mr. TULL without feeling a strong desire to show some mark of high respect to the memory of the Author; what then ought our indignation to be at seeing him pillaged and plundered by whole bands of writers on what they call "the Drill Husbandry," who never so much as mention his name, and who have, perhaps, purloined from one another, till they themselves would be unable to guess, who, in any one instance, who was the original thief. One thing, however, they take special care of; and that is, so to disfigure, to mar, to confuse and to confound his matter, that he must be a clever man indeed who is able to make top or tail of what they write and publish.

Shameful treatment of Tull resulted from his noble purpose

It is curious enough, that he was, even in his own time, an object, at once, of plunder and of calumny. He says, in the Memorandum, in which he takes his farewell of the public, "some have told me, that the whole Treatise should have been entitled, Husbandry Mathematically Explained; others, Agricultura Tulliana: and this last is the title now given it in Ireland. It is said that mine is the first book of Agriculture that has happened to be pirated; and that upon the first notice of it, I ought to have desisted; because I must be a loser by proceeding any further at the press; and that I could have little obligation to a country whose laws did not protect me in the property of my labour (which was the original foundation of property in most things) and of my expense that is joined with it. The best apology I can make for this my folly is, that it is natural for the true parent rather to lose the property of his offspring, than not to endeavour to preserve the life and well-being of it, though in the hands of enemies."

Would this apt and beautiful allusion to the story of the true and false mother, who brought their dispute before SOLOMON, have any effect on the pirates to whose baseness Mr. TULL here

alludes? Not it indeed; except to induce them to add abuse of the author to the stealing of his property. However, it is the laws, as he so well observes, the injustice of which, the matchless injustice of which, exposed him, as they still expose every other man of talent, to the blunderings of these villains. Certainly a man is under little obligation to a country whose laws do not protect him in the proprietorship of his labour. See with what care the proprietorship of lands, of tithes, of manorial rights, is fenced round! You may not set your foot upon another man's land without paying for damage of some amount; and you may not do it a second time without heavy punishment, bodily or pecuniary. Nay, look at the laws to preserve wild animals for the sport of the landholders; and, when you have looked at them well, when you have examined into all their pains and penalties; turn and see the protection which has been provided for the property which a man has in a book which is a thing of his own creation, the fruit of his own skill and genius, the result, perhaps, of years and years of labour, and, possibly, the only provision he may have to leave for a helpless family! When you see laws like these: such laws to protect the authors of books; and such laws to preserve partridges, pheasants, and hares; no questions are necessary; you know, at once, by whom the laws have been made.

I have derived so much pleasure, and so much real advantage from the reading of this work, that I cannot help wishing to see it in the hands of others. I was born and bred amongst affairs of gardening and farming. I had read a great deal too about them; but, till I read TULL, I knew nothing of the principles. But what struck me most forcibly, when I came to read TULL, was, that all that I had read before, that had anything like principle in it, had been stolen from him; shockingly disfigured indeed; but still, whatever there was of good was his. Here are, in fact, all the whole code of principles of vegetation. They apply in all cases. Whether in the corn-fields, the pastures, the gardens, the coppices, the woods, or the forests. The work does not treat of the detail of planting trees, for instance; but, when you have read it, you will never plant a tree badly. You will take care, that the earth shall be finely broken; that it lie close to the roots; and that it not be tumbled into the hole in clods. Mr. TULL does not treat of transplanting field plants at all; and he (who wrote when Swedish Turnips had not yet been heard of in England) says, that transplanting is not so good a way as sowing in rows and horse-hoeing. But it was from reading TULL that I came to take, by preference, dry weather to transplant in, and not the showery weather, chosen for that work by all the writers, French as well as English. TULL had taught me, that it was finely broken earth that I ought to have about the roots of my transplanted plants. This I could not have if I transplanted in wet. The instructions, on this head, given in my Year's Residence a seedsman in London told me contained the most valuable discovery that he had met with in any book. It certainly is valuable; but though I had had instances of the effect, I never knew the cause, and never should have attempted the thing on an extensive scale, had I not read TULL.

Purpose for republication: to provide Tull a service of justice, to share with others the prosperity gained from it, and to expose those who have plagiarized

If there were no other motive for re-publishing this work than doing the Author justice, that ought to be motive sufficient. He has been plundered by English writers not a few, and by Scotch in whole banditti. I wonder they are not ashamed of pillaging so flagrant; but when once a man can bring himself to do such things, he has little shame left. Mr. John Christian Curwen, who has won so many Agricultural prizes, has an account of the effects of ploughing between cabbages and between potatoes. These experiments he takes to himself. He has an experiment proving that moving the ground in dry weather makes it moist. This discovery he ascribes to BISHOP WATSON! What a pretty fellow this Bishop must have been, if he pretended to be the discoverer of this! As to

the effects of ploughing between cabbages and potatoes, there were, indeed, no cabbages in the fields in TULL'S time; but he describes the effect of digging between them; and as to Mr. CURWEN'S potatoes, the experiment, in all its detail of operations, is almost literally from TULL! Let any man look into the Chapter of TULL, On Hoeing, towards the close. Then turn to Curwen's Hints on Agriculture, where he speaks of growing potatoes in squares or beds; and then say, whether plagiarism quite so scandalous was ever seen before. This gentleman's attachment to his own literary progeny is well known. When the late Minister, Perceval, had made a Bill of his altogether another thing; had taken the whole of the enactments away; had altered even the preamble; had made it as perfect a changeling as every gipsy left in a farmer's wife cradle; had stripped it of all but its mere name, Mr. CURWEN owned it, fathered it, and hugged it with paternal fondness. He ought, therefore, to have some consideration for the claims of others to their own.

This republication of TULL will strip many an agricultural philosopher of his borrowed plumes. The work, from being in an awkward form, and from containing mechanical matter which has been rendered useless by the many and great improvements in agricultural machinery, has been, comparatively, seldom seen. It has been, in a great measure, unknown to the public; and has, therefore, been a very convenient mine for plagiarists to resort to. This will now be at an end. The work will be accessible to everybody; the public will no longer be imposed on, and the memory of the author will, at last, receive something like justice

WM. COBBETT.

Kensington, 20th April, 1822

THE FIFTH EDITION

BY AARON BRACHFELD AND MARY CHOATE

P R E F A C E





Introduction to an old, useful and dangerous book

Several hundred years ago when the First, Second, Third and Fourth Editions were published, this book birthed both the scientific and industrial agricultural revolutions, revolutionizing agriculture and society to allow for a new era of industrialization and democratic political freedom, forever changing the course of human history. Now, by the improvements made to this edition, this same book is prepared to open another new epoch in human history defined by virtually unlimited resources.

All that we propose may seem shocking at first, and what our lessons imply may seem outrageous, but what we claim is none-the-less true – and those who doubt would do good to remember that the promises of industrialization made by earlier editions of this book seemed equally outrageous and shocking to the pre-industrialized societies to whom they were made. So we reaffirm: however shocking and outrageous the statement sounds, now inexhaustible supplies of food, medicine, fiber, energy and fuel may now be easily obtained with minimal effort and cost from

even the most barren deserts, the highest rocky mountains and the deepest oceans – even while the deep soil of the fertile valleys overflow with delight and the prosperity that will follow is as incomprehensible as industrialization was to those who had not witnessed its wonders.

In these pages you will learn how to raise from dead lands the bread of life, how to conquer the modern terrors of pollution and environmental change. You will learn how to secure your civil rights. You will learn how to plant your seeds at a proper depth, how to care for them as they grow, how to feed and nurture your people. You will learn how to harness and work animals, plants, fungi and microorganisms to cause deserts and oceans alike to yield inexhaustible wealth. You will learn how things work and why things must be done in particular ways and gain the skills required to improve the science further.

You will learn to think twice before suggesting that the Earth, which has always provided for all of humanity's needs, has somehow become barren or unloving in recent years, you will never again believe that some lands are naturally poor and that the people who unfortunately reside upon them will always be unhappy. You will never again even think that the fury of the weather is to blame for the resource crises we face today. No, you will understand that the blame is our own for the fault lies in our agriculture.

Though Jethro Tull's science still reflects state-of-the-art knowledge, this 5th Edition has been supplemented to include those many advances made since the 17th Century, and these advances have been applied to the ancient methods of Tull to develop a New Deep Hoeing Husbandry that requires absolutely no herbicide, pesticide or fertilizer (organic or otherwise), and an entirely new method of animal husbandry that, in applying the science of Jethro Tull to animals, revolutionizes animal production.

Both improved agricultures increase the profits of farmers enough to allow anyone – whether they will urban farm from an apartment or cultivate millions of acres – to farm indefinitely, perfectly sustainably, while improving the ecology and their yields annually. These new methods are shock-proof and ready for the tests of a changing climate, and allow the cultivation of deserts, mountaintops, coastal bays or even deep oceans as readily as the most fertile river valleys. This unlimited and affordable production of energy, clean water, food, fiber and fuel, if widely adopted in a new agricultural revolution, will feed the world.

At last, nature's fury is tamed and nothing can prevent the harvest but the almighty will of God - but even this is secured for by the goodwill of this most excellent method towards the beautiful creation. Read this book, and gain the favor of man and nature alike; rise – as Jefferson, Washington, Madison, Monroe, Cobbett, Young and so many people did by reading previous editions of this book – to the pinnacles of power in this new age of humanity. The learning of this book is no frantic leap to a new way of thinking, but is the drum beat of a disciplined march towards the progress of civilization, calling you and all your friends towards the bright sun of a new age.

In this book you will learn the causes, the origins and the nature of agricultural wealth; you will learn you may be free from suffering. You will learn that you are indeed your own master and need not rely upon anyone else for your defense or prosperity, you will learn that you, by yourself, may provide for the general prosperity and defense and how to rise to the leadership of your community. Teachings such as these are dangerous lessons indeed, for they are the making and building of nations, and while three previous editions have been suppressed, this 5th Edition anticipates the consequences by also providing what learning you will subsequently require in the political organization of democracy and cooperatives.

Do you not yet see that you hold in your hands the very flywheel of Democracy into which the energies required for your freedom have been dutifully stored? Your loving ancestors, with

dutiful foresight, understood there would come a time for its necessity when their descendants would need to open up the chests of wealth in the Earth against terrible challenges. Now is that time. Seize this moment, do not delay! Indeed, there is no exaggeration in saying that, here, in your hands, you hold the seed of humanity's freedom from want, the end of war and fear.

In the past, Emperors, soldiers, Senators and Ministers have desperately sought for this ancient work to preserve their nations. This is a dangerous book! Despots have sought this book for its destruction because, to secure their homes forever, democratic revolutionaries around the world have found within its pages the strength, so well stored within this flywheel, to rebel against their tyrants. This book, more than any other, is the inspiration for the great American Republic, whose loyal friends sang its praises in Philadelphia. You hold in your hands not only your own economic prosperity but that of all free people everywhere and we humbly beg you to consider its worth to you.

Thomas Jefferson recommended this book to Madison, Monroe, and all those studying law or preparing for government (*Life of Thomas Jefferson*, Randall. p 53-54, Letter of Thomas Jefferson to Bernard Moore), and bought not only copies of the work for his friends, but even sometimes (for Madison at least) provided a Tullian plow. Monroe's Presidency coincided with the 4th Edition of the Horse Hoeing Husbandry, edited by the sometimes fugitive English Parliamentarian William Cobbett who had found asylum in America and became exposed to the Tullian system of agriculture.

George Washington, though more hesitant than Jefferson in offering advice, did practice the Horse Hoeing Husbandry as soon as he read Tull's book in the 1760's and was able to convince his friend the Englishman Arthur Young to do the same. Norfolk was subsequently transformed by Arthur Young from sheep pastures (and poor ones at that) into rich barley land by Tull's method, and Young became a lifelong outspoken promoter of Tullian agriculture in England. The great "Turnip" Townshend, of course, had the highest regards for Tull and his book and recommended the method widely.

The list goes on. Some of the very best farmers in our nation's history were great because they practiced the methods of Tull, some of our finest leaders were able to become leaders because of the vast wealth they acquired by Tullian agriculture. To be like Midas and turn, as Washington said, every land you touch to manure is a special gift indeed.

It is true that since the Chemical Revolution of the mid 20th Century anti-Tullianists have done their best to eclipse the great work of Tull, but this is no reason to shrink from their challenge. The time is ripe for a reprisal and counterargument to anti-Tullianism and we champion the call for sanity. Sane farmers, gardeners and consumers do not want herbicide, pesticide or fertilizer and would very much welcome this great effort by Jethro Tull and his subsequent Editors.

For that matter, because chemicals are so unpopular, all those who eat would be interested to learn what is in it, and though in some modern journals it is derided by the likes of Dr. Warkentin, it has always faced opposition of his kind: baseless, factless, inflammatory and false. Yet, that Tull's enemies would continue to find no better argument to his work after even 181 years since the last edition (and 279 years after the 1st Edition) than baseless personal attacks and the purposeful misrepresentation of his work certainly says something to its relevance and recommends, if only by such attention paid by his enemies to the Horse Hoeing Husbandry, Tull's work to the public. Indeed, this attention has encouraged articles in praise of Tull the world over.

Open this book. Read it. Then read it again. Remember the lessons within! Learn the importance of digging deeper. Now is the time to break new ground in everything you do. Cherish this book, protect it as an inheritance for your children. This 5th Edition of the Horse Hoeing

Husbandry is the most comprehensive book on farming ever written, but more importantly, it professes methods that allow novice, small and micro-acreage farmers who have none of the advantages of wealth or technology to compete easily with well-endowed large-acreage experts. It allows anyone anywhere, whether they live in deserts or upon the living rock itself, to feed themselves, their families and all those whom they love. With an inconceivably small quantity of land and other resources, a person can be not only free, but wealthy! It trains the mind against the rigors of the world, it prepares body and soul to work for the betterment of humanity.

Here is the key to the shackles of financial and political bondage, the prisons of hunger, fear and want, here is the fountain of liberty: cast off your chains and slake your thirst! Within these pages even the smallest citizen may learn how to loose themselves from the chains of their masters, the weakest among us may learn how to defend themselves and provide for all their wants. Be so emboldened as to dream greater than your freedom! Dream of heroism: by such brave words as are in this book, the greatest citizen may learn how to perform awesome heroisms, the likes of which Hercules himself would not have dared.

Here is a lasting peace between people founded upon a general prosperity of endless successful crops; here is a brave beginning to a friendship between all living creatures, the foundation of true interspecies cooperation that advances the arts of domestication beyond those Neolithic practices still so widely practiced today. It is a book on agriculture, and is one of the most beautiful and sublime flowers of the scientific revolution. The glory of its restoration can belong to you when you dutifully present it to your children as their inheritance.

Frankly and without the least exaggeration, inexhaustible resources of food, energy, fiber, fuel and medicine have always been demanded, even since ancient times. Harmony between industrialized agriculture and a wild, free nature, political liberty and financial independence has always been dreamt. Now, in these our modern times, such inexhaustible resources are actually required as the Earth herself groans under the weight of our burdens. The Horse Hoeing Husbandry, suppressed and embattled for nearly 300 years, for a 5th time revived and updated, once contained between its covers the knowledge to topple tyrants. Now it contains within it the knowledge to deliver humanity from material wants forever and change the very soul of human nature.

Why Monceau sought republication of Horse Hoeing Husbandry

The Horse Hoeing Husbandry was published twice by its author, and subsequently by several editors. While the history of the work will be discussed at greater length later, it is meet to introduce the importance of this work by discussing its importance to its various publishers and editors so that the reader may more appropriately apprehend that desperate and immediate need of the public for its reference again.

Some words will be provided to introduce Monceau's reason for publishing the third edition, and to introduce Monceau and his employer.

Noailles, Foreign Minister of France, Marshal of the Army, commands investigation into new Tullian Method in the interests of the State: a new foreign policy of defense by plowshares instead of swords

When Adrien Maurice de Noailles, Duke of Noailles, Marshal of France became Foreign Minister in 1744, he was or quickly became aware that an improved agricultural method had been developed in England. He immediately sought to gain the benefit of the improved agriculture for France and commissioned the greatest scientist of France, du Monceau, to study it and diffuse it among the French farmers and produce the 3rd Edition of Jethro Tull's great work, the first 2 editions having been published by Tull himself.

With the Little Ice Age in full swing and an unpredictable climate becoming more hostile to agriculture annually, Noailles remembered the rebellions and anarchy that followed food shortages and understood food security meant national security. Perhaps "remembered" is a soft word, for Noialles had helped the Irish and Scotch famines transform from regional tragedies to catastrophes that threatened the very English throne, and the pain of the civilian attacks on military grain convoys in France were recent. Just as English disasters of the 1739 and 1740 potato famines were largely political and governmental by nature, just as France somewhat helped in causing more of that political trouble for England, Noailles understood what defense against an English intervention during a French famine required.

The Minister was not alone in his worries or understanding: the French economist, Charles Louis de Secondat, baron de La Brède et de Montesquieu, had just demonstrated the law of famine situations and the universal rule that "the interests of the individual lie in the betterment of the whole." The subtlety of Noailles presented a broader purpose in adopting the new Tullian system: peace could be better defended by plowshares than by swords.

The Romans lived and died by war, saying that those who want peace should prepare for war. The great Noailles dared to dream beyond this long-held belief and conceived of a better way: he understood that those who desire peace should prepare for peace; that peace – not war – was worth dying for, and demanded the full attention of the State. He understood that prosperous agriculture meant peace.

Neither hunger nor war were new to France ("Hunger...in the seventeenth century was always a social phenomenon...The lavish feasts were also social and provincial phenomenon, but only happened on rare occasions." *French Peasantry in the Seventeenth Century*, Pierre Goubert 1989), and indeed, while neither hunger nor war were new to France, the worries of Noailles would be proven accurate later in the Century when the French Empire was toppled by the hungry poor who could

not even afford the cake their Queen suggested they eat instead of bread. The failure of du Monceau to adequately translate English to French resulted in the failure of his nation.

Why Cobbett sought republication of Horse Hoeing Husbandry

Some words will be provided to introduce Cobbett's reason for publishing the third edition, and to introduce Cobbett to the reader.

Failure of Tullian agriculture in Europe, success in America

Do not suggest that the promises of the warrior and the lawyer were broken: for in some of the rebellious colonies, those which would federate to make an independent Republic, Jethro Tull had found his greatest acceptance and following. In this new Republic, his methods allowed even the least educated, least wealthy, least powerful citizen to, with minimal education and training, join the elite of their society and became an inspiration for a new Jeffersonian system of democratic Republics.

Yet it is true that in Europe the promises were not kept. In France the willing farmers could not understand the language of Tull, but in England many farmers were unwilling to even trial the methods. The new system of agriculture could not be diffused, no matter how simple it was, no matter how much Tull tried to promote it through demonstrations, arguments and publications. Even those who pirated Tull's work (and his was the first book on agriculture to be pirated) failed Tull's hope for the preservation and diffusion of his work. Why would farmers remain stubborn enough to spurn a method that would have increased their wealth and security, served their nation and gained them honor? Was it a kind of laziness, this basic corruption of the farmers?

Said Tull, "it is objected that gentlemen will not take the trouble of studying it. The same objection may be made to algebra, navigation, or any other art or science; yet this is no reasonable objection against the writing of it, only against the unreasonableness of him who would understand it without the necessary trouble of studying it" (Supplement, 1750).

He knew his work would not be as well read as those who would be benefited most by reading it ought to. He also understood that even those who practiced it successfully would convert few to the new method, pointing to how "the people of Madrid or Lisbon do not turn Protestants when some English live there and converse with them" (Supplement, 1750).

Tull was clearly was not ignorant of the problem, and shed some light on it:

It was about 17 years ago that I was walking with a farmer in this part and saw on one side of a hedge a little field in the occupation of a gentleman who had fallowed it early, and plowed it three or four times afterwards, and sowed it with wheat without dung: on the other side of the hedge was a field sown with wheat on once plowing, according to the old custom, well dunged: it was then near harvest, and the farmer judged the crop of the Anti-Virgilian field at four quarters[26] *to an acre, and the other at two bushels, or three at the most; and I afterwards found that he was right in his valuation of those different crops. He said the field which had the poor crop was always accounted the better land of the two, though of the same sort. He said too, that his late father used to observe that this custom of once plowing did never produce so good crops as the same sort of land did in places where it was the custom to plow often; and the farmer*

[26] A quarter is 8 bushels, 4 quarters is 32 bushels. –A.B. & M.C.

himself could remember fifty years and never found their once plowing succeed well. I then asked him the reason why the continued such a bad custom, which was never known to succeed. His answer was, "we are still in hopes."

Tull goes on to explain that later, such hopeful farmers would adopt a compromise, planting his crops in rows but not tilling aisles.

It has always been the aisles – which are the most important component of the system – which farmers resist most fiercely. Though they are ready to adopt rows and properly space their plants, they will not feed them with tillage, though tillage could easily be undertaken with profit and little or no cost of time to the farmer.

This laziness – the corruption – that would prevent a farmer from feeding their plants to earn more money, to feed more people more affordably, to present a better inheritance to their children is of great concern, and its origins require illumination.

Malicious discouragement of farmers by enemies of the State result in Platonic corruption

Laziness is only part of the answer. The farmers compromised, and this is important to recognize. They compromised between two arguments because there were two arguments. In America, where there was much less scientific debate, farmers adopted the Tullian method wholly because it was advocated without substantial challenge and, indeed, the elite and the greatest farmers encouraged their neighbors to adopt the new method.

In Europe, there was debate with the enemies of the Tullian method and farmers did not trial them. They did not try learn the importance of the aisles, but immediately surrendered to both arguments simultaneously, if they heeded Tull's method at all. We will explore this counterargument to Tull, and why it was so convincing that farmers would not even attempt a trial of aisles and Tullian methods.

It bears saying first, however, that the counter-argument is a dreadful one. An argument against making trials because there could be some risk of failure is a bad one, especially when a trial requires less land than a human being requires to lay down upon. A farmer who would rather laze upon the ground than work at improving their art upon it certainly is not persuaded to do so by argumentation alone: they have a natural inclination to declination. Yet such laziness, defying the natural interests and instincts of a farmer, is alarming: it is a Platonic corruption, and it is not amiss to describe such farmers as "corrupted," for they no longer fulfill their natural roles in society or the world, nor do they seek their own betterment logically and with reason.

Though the interests of the State and citizen are, as the interests of Monceau and Noailles were, in the development of agriculture, there are enemies of the State and citizen who prefer to selfishly profit by lawless corruption and thus pit themselves, directly or indirectly, against the interests of agricultural innovation. In example, today we see anti-Tullian arguments coming from those companies which produce the herbicides, pesticides and fertilizers that are entirely unneeded by Tullian farmers. These selfish companies earn profits at the expense of the interests of their customers and their nation and gladly corrupt farmers from undertaking the necessary trials or investigations to question the use of herbicide, pesticide and fertilizer. The methods of these corruptors are many and anciently practiced, and need no exposition. To sin is human.

Yet it remains that to discourage farmers from even trialing Tullian farming is a disservice to the farmer and their nation. When farmers undertake unbiased trials to discover for themselves whether the Tullian method is superior, they discover that they are superior. When they are

discouraged from undertaking trials, they never gain the opportunity to learn. An unbiased farmer can see their neighbors prospering and be convinced to undertake a trial, but a biased (or corrupted) farmer will be discouraged from the attempt and believe that what they see is an anomaly unworthy of further investigation.

The opponents of Tull and Monceau undertook just this very discouragement. The subversive techniques of these opponents not only spread misinformation about the success of the method, but diffused false descriptions of the method so that those who would try it would fail, undertaking misinformation as a kind of false refutation, trusting that when sufficiently obscured, it would pose no threat.

Defamation, discreditation and other shameful attacks

Besides these damaging efforts, enemies of Tullian agriculture undertook to defame the authors and publishers. Socially, they were shamed. Politically, they were criminally accused. These anti-Tullians disclaimed the work and disdained it even while republishing the work or portions of it sometimes correctly, sometimes with deliberate errors. They even lied to say Tull had stolen his inventions from Italy or Spain or China, and claimed Tull had stolen his research from others!

Tull, as a lawyer, would certainly have been familiar with these cowardly techniques. Shamefully outnumbered by opponents willing to use ignoble attacks and being unwilling to undertake similar measures, he and his friends could not defend the Tullian method from its near-demise.

But do not suggest that all the damage to the work was done by malice: some well-meaning friends tried to republish the work in Tull's defense, but their edition is riddled with errors. For that matter, Tull's editors and plate engravers of the First Edition, probably out of no animosity, also crippled the work. When Cobbett republished the Horse Hoeing Husbandry, he attached to it the campaign of corruption reform and its associated stigma.

These little hurts by friends, however, pale against the malicious attacks of Tull's enemies and amount to very little: there is no shame and much nobility in the stigma of political reform Cobbett undertook; his publishers and engravers, though active editors, failed to actually hinder the work and may, in the balance, have improved it some; his friends, in producing a "highly corrected" version attempted to do what Monceau had already led the way by with limited success.

Farmers discouraged from undertaking trials to improve their agriculture by laborers and farm managers fearful of jobs, "learned" men afraid of competition

Some of his opponents were the "learned" men who feared the competition of an "unlearned" farmer. But the greatest harm came from the arguments made by those who feared their laboring jobs would be eliminated by the mechanized system. Farm managers discouraged their masters to trial it, believing that their friends (and they) would be quickly out of a job. Tull encountered with one of these discouraged farmers to little avail.

Jethro Tull relates in his 1750 supplement how he received a letter from a gentleman who was considering undertaking the new agriculture. The gentleman had asked his farm manager to look into the new agriculture and give his opinion of it. The farm manager did not advise the gentleman to undertake the new agriculture. Tull thought that asking the employees of a farm about

adopting a method that reduced the needs for labor was like a Catholic asking their Priest in confessional their advice on Protestantism.

These lies from laborers and managers were crippling indeed. Why would a farmer undertake a trial of something that works today by accident when he has heard so much argument against it by his farm manager and laborers? Couldn't the farmer see those arguments were based on false logic?

Not all laborers and managers were thus biased against their employer. There was significant trust between the farmer and their employees in many cases, and a trust between those employees and the leading authorities on agricultural science. But here is where the abuse of power can be best seen: no farmer is apt to suspect their trusted advisors and employees, especially when it is their job to learn and experiment for their master. And those without advisors and employees are apt to trust those very learned authorities that were spewing pernicious lies against Tull. The farmers, while not uneducated – the subject is one with which that they are very well familiar – were very trusting. They were ignorant, not of farming matters, but of human nature: farmers are as intelligent as any other member of society, and even the wise among us will fall to tricks of logic if they are caught unaware.

We discussed trials with a farmer once who refused because, should he increase his production, he would have to pay more taxes and more rent. We asked whether his new income would be still greater than his taxes and rent, and he said it would be. Why then not increase revenues and pay more taxes and rent? Because he hated paying taxes and rent. Another farmer discussed the market value and cost of conventionally grown crops, and we showed to him if he would but try a different crop he might earn better income; this was refused for he was happy with the way things were (he was, at the time, losing money on every acre and laboring to compensate the difference): his family had grown potatoes in that way since time out of mind, and so would his children. The farmer who would dislike to earn more money because they would pay more rent or taxes, or who would rather lose money on every acre rather than try their hand at a new crop, who will lose the farm of their fathers by continuing to practice their erroneous techniques appears, at first, to be unintelligent and uneducated, but is not necessarily so.

Regardless of their native intelligence, they have been tricked and deceived: even an intelligent person can be easily tricked.

Such beguiled farmers lose their lands, their gardens, their little Edens, their hopes and joy; their families are dispersed through the lands upon the wind. Through malicious lies told to them with the intent to harm a third party, they are themselves destroyed, an unwilling party to the sin and the relentless justice that follows.

And it is unlikely that the farmer ever suspects those who betrayed them, those who were intent to destroy Tull's work! The farmer trusts the expert until the day they leave their farm behind them, never to return, and even blesses the expert for all the help they rendered – even as the expert rended their farm to pieces!

While Tull's opponents could not overcome Tull in a fair trial with an unbiased jury, they could bias the jury and keep Tull out of the court.

History and legacy of the malice

Yet the direct enemies of Tull are dead, gone and forgot. They were gone when Cobbett published his edition. Who is causing mischief now? Who are the new anti-Tullians? Who would

treasonously corrupt farmers against the interests of their people and their State? Who are these enemies of the State, of Law, of Truth, Peace and Prosperity?

These corruptors need no long-term organization against Tull, for they gravitate to his opposition as naturally as they try to profit from the hateful, wasteful destruction of the good Earth their God made for them to enjoy. A company that manufactures fertilizer has natural interests against the State, and will naturally seek to convince farmers they ought to buy that which is bad for their land and bad for their farm's finances. Out of jealousy, out of fear, out of greed, out of a poverty of the spirit such people are moved to lie in hatred so that they may sow discord and misery. Gluttonous for the despair of their vainglory, they betray that which ruined them: they are discontent with civilization and have become antisocial. Perhaps it is not too much to call these antisocial sociopaths?

These sociopaths sell poisons to parents, telling them that the poisons will protect their children by killing insects when they know the poison will also kill the children, they pollute radioactive wastes in the rivers and oceans their neighbors fish from and swim in while telling, earnestly, their neighbors that the fish and waters are safe, they invent and sell weapons of hideous, unspeakable terror with the excuse that it provides for the general security, they arm insensible robots with the tools of death while arguing that these machines extend and improve life to aid the progress of civilization. Such sociopaths conceived of an Organic Act that allows the selling of conventionally grown foods at unconventional prices through a complex deception of the public. They produced "miracle" medicines that cause secondary diseases that require subsequent medicines, which cause tertiary diseases, which...kill the patient.

Yet it is no less outrageous that that these sociopaths also develop and encourage farming practices that decertify the land and impoverish the farmer, and discourage and attempt to destroy those which are wholesome and good for farmer and land.

Thomas Hobbes, and much later Dr. Sigmund Freud, sought to understand this phenomenon of suicidal antisocialism, this discontented hatred of civilization and peace. Both Freud and Hobbes understood that there was a social relationship between people that evolved into a corporate entity that Hobbes termed "Leviathan," and Freud termed "civilization." It is the responsibility of the leaders of the civilization – the nobility – to inspire the necessary virtue within the citizens – that necessary love of prosperity and peace – that allows citizens avoid such insanity. This love of civilization is a love for honor, and requires an honorable nobility to recognize and cultivate nobility within the citizens.

The Horse Hoeing Husbandry earns citizens great honor, and would be despised by those who hate honor, honor being the bond of love between citizens that forms the State.

Horse Hoeing Husbandry is an industrial method for an industrialized society: it increases labor market wages. Laborers wrong to fear it

The Horse Hoeing Husbandry earns citizens great honor. It frees the farmer financially to serve no other master but the State, and allows profitable agriculture on a scale that allows every person to farm. And, though our population swells, there is plenty of land still to farm on for everyone to enjoy – if all the land in the United States were divided among its people, there would be approximately 12 square miles per person – 48 square miles per family of four people; even in Japan, that overpopulated land, there would be .75 acres per person – 3 acres per family of four. While some land must be reserved for wildlife, and some land is unsuitable to agriculture, this still leaves

more than enough arable lands to sustain family farms. Though not everyone needs to or wants to farm, allowing those who do to produce wealth and remove themselves from the glutted labor pool would be a boon to those who do not wish to farm.

Yes, think of the boon to those who do not wish to farm: they would find a labor market unglutted by surplus hands and better wages! If the government allowed our people to farm, they would grow strong with their own or their neighbor's agricultural industry. A glut of laborers need not depress labor wages in an industrialized economy.

Industrialized agriculture for an industrialized economy makes sense.

It is ironic and maddening that Tull is often accused of putting farm laborers out of work, of depressing labor wages through an industrialization of the economy when Tullian agriculture, an industrialized method, is exactly what the industrialized economy requires to stabilize labor wages by preventing a glut of labor in the market.

It is ironic and maddening that Tull is often accused of putting farm laborers out of work, of depressing labor wages through an industrialization of the economy when Tullian agriculture, an industrialized method, is exactly what the industrialized economy requires to stabilize labor wages by preventing a glut of labor in the market.

When Tullian agriculture is undertaken, small farmers can be as or more efficient and profitable than large conventional farms.

Modern menaces introduced: monopoly of land causes undue hardship to those who would enter the agricultural industry; Cobbett's purpose for republishing still relevant

Yet even as attempts are made in America by families to undertake such agriculture, they find an unfriendly government thwarting them with outrageous laws and unrighteous unfair competition. Where laws do not outright prevent agriculture, they do not protect the freedom of the land from monopolization by large farms; the government props up conventional farms and allows them to stay in business despite their unprofitability. Why, even as this book was going to print, the City of Detroit was considering turning much of its urban core into farmland...and gifting it to a single farmer, a friend of the Mayor.

Yet not all modern monopolization of land is so outrageous and the subtlety of it must be discussed to introduce Cobbett's preface, to illustrate and demonstrate the continued relevance of Cobbett's love for Tull's work – even as we have demonstrated the continued relevance of Noailles' love for Tull's work – for it betrays a corruption of the Jeffersonian ideals that Cobbett held dear.

Cobbett's Agrarian Republic and Jefferson's Agrarian Democracy

Cobbett saw the Horse Hoeing Husbandry as a way for farmers to become financially independent citizens, able to undertake their government. The idea that financially independent farmers were best able to undertake the burdens of government was not a new one, and the foundation of Jeffersonian Democracy lies in the hopes Jethro Tull penned in his famous technical manual.

Thomas Jefferson originally studied Tull because in America labor and manure was scarce and land was plentiful (*Introduction* to Thomas Jefferson's *Farm Book*, edited by Edwin Morris Betts, 1999). His admiration for the functional methods of Jethro Tull would bear fruit when in tribute Jefferson invented a "Mouldboard Plow of Least Resistance," used the hillside plowing techniques designed by Tull to prevent erosion, and conceived of a representative democracy of farmers. These ideals undoubtedly influenced Cobbett, whose involvement in the Reform Act of 1832 echoed the call for a representative, agricultural Republic.

The necessary failure of the Agrarian Democracy or Agrarian Republic is due to the agrarian economy's natural evolution to monopoly

But what has become of these noble hopes? Is it suitable to found a Republic upon the tilled fields of farmers?

The Republican and Democratic ideals at first seem to favor an agrarian economy. The atomistic nature of many free and (roughly) equal citizens participating in an unconstrained economy does seem appropriate. However, the agricultural economy is highly unstable in an atomistic form, and naturally evolves into a monopoly without government protection of this limited and necessary natural resource.

Monopolies threaten a new Tullian revolution

Besides laws that actually prohibit or limit agricultural activities on many of the remaining small and medium sized farms, where farming is still allowed on small and medium sized farms, larger farms are able to easily squeeze out their smaller competition. This is leading to a monopolization of land.[27]

[27] Shaila Dewan of the New York Times in her article, *In Mississippi Delta, a Promising Summer Washed Away by the Fall* (November 22, 2009) profiled a farmer whose soybean crop had failed due to an exceedingly wet autumn. His family had barely survived government antagonism because they were of African origin ("For Mr. Hart and his friends, the specter of failure has a double burden because they are among the few black farmers to have survived years of discriminatory policies by the federal Farm Services Administration, which were detailed in a successful class action lawsuit. As part of the settlement in 1999, the Agriculture Department admitted that it had for decades made it harder for black farmers to get loans.") but now could not survive the pressures of land monopolies: "In December, the land rents are due for next year, but without a crop, the farmers may have no money to pay, and larger farmers will snap up their acreage. Mr. Clark predicted that small black farmers would be unable to return. 'If I get out of it,' said Mr. Clark, who rents mostly from black landowners, 'this land is gone.'"

Not only the Clarks, not only Black landowners, but every small farmer or renter faces the threat that larger farms will be able to gobble up their small acreages. Unlike in Jefferson's day, there is no surplus of land for small farmers to turn to when the larger farms have bought up all the land.

Brian M. Riedl at the Heritage Foundation (2002 *Still at the Federal Trough: Farm subsidies for the rich and famous shattered records in 2002*: http://www.heritage.org/ Research/Agriculture/BG1542.cfm) showed that nearly three quarters of subsidy money goes to the top 10% of recipients. Riedl argues

Monopolies derive their market power from barriers to entry (those circumstances that prevent or greatly impede a potential competitor's entry into the market or ability to compete in the market). There are three major types of barriers to entry; economic, legal and deliberate, and large farmers in America enjoy all three fortifications to their market position.

But the issue is less of how the monopolies are creating barriers, but why. There are many reasons why monopolization of land is occurring. Because large farms have more assets per operational cost than small farms do, they are better able to withstand crop losses and other disasters through credit.

that the subsidy money is helping large farms buy out small farms. "Specifically, large farms are using their massive federal subsidies to purchase small farms and consolidate the agriculture industry. As they buy up smaller farms, not only are these large farms able to capitalize further on economies of scale and become more profitable, but they also become eligible for even more federal subsidies—which they can use to buy even more small farms."

Riedl draws a pessimistic outcome:

Eligibility for farm subsidies is determined not by income or poverty standards but by the crop that is grown. Growers of corn, wheat, cotton, soybeans, and rice receive more than 90 percent of all farm subsidies, while growers of most of the 400 other domestic crops are completely shut out of farm subsidy programs. Further skewing these awards, the amounts of subsidies increase as a farmer plants more crops....large farms and agribusinesses – which not only have the most acres of land, but also, because of their economies of scale, happen to be the nation's most profitable farms – receive the largest subsidies. Meanwhile, family farmers with few acres receive little or nothing in subsidies. In other words, far from serving as a safety net for poor farmers, farm subsidies comprise America's largest corporate welfare program.

The result is a "plantation effect" that has already affected America's rice farms, three-quarters of which have been bought out and converted into tenant farms. Other farms growing wheat, corn, cotton, and soybeans are tending in the same direction. Consolidation is the main reason that the number of farms has decreased from 7 million to 2 million (just 400,000 of which are full-time farms) since 1935, while the average farm size has increased from 150 acres to more than 500 acres over the same period...When President Franklin Roosevelt first crafted farm subsidies to aid family farmers struggling through the Great Depression, he clearly did not envision a situation in which these subsidies would be shifted to large Fortune 500 companies operating with 21st century technology in a booming economy.

To contrast policy, in Europe, the Common Agricultural Policy has provisions that encourage local varieties of foods and pays out subsidies based upon total cultivated area and not production.

While small farms receive more payments in relation to value of their crops than big farms, they are receiving less and are less able to take advantage of these proportionally greater payments because of their asset structure.

The number of large farms (more than 1,000 acres) is increasing while the number of smaller farms (excepting those under 50 acres) is decreasing (USDA Census of Agriculture, Volume 1: http://www.allcountries.org/uscensus/1097_farms_ number_and_ acreage_by_size.html). Only those farms less than 10 acres are strongly growing. One reason why the number of micro farms is increasing is because many of these small "farms" are actually residential units.

Subsidies for large farms, of course, do not help retard the progress towards monopoly, but the legal prohibition of farming near many urban areas (where small farmers must go to reduce transportation costs) actually encourages monopolization of large farms.

Though the government's discouragement of small farmers is deliberate, it is doubtful whether the large farmer has enough dislike for the small farmer to purposefully exclude them from the market.

Winston Churchill, in an address to the House of Commons on May 4, 1909 reacted to the land monopoly near his English cities by understanding that such behavior is not morally reprehensible, but natural, given the interests of the landlord. While he draws his ire from the monopolization of urban lands, his point, that it is not the criminal but the law itself which is at fault, is important to note. Also important is his correct understanding that land is not a resource open to free competition, but a public and common wealth that must be rationed in the interests of a stable Republic.

By using more than what is needed, a citizen bars their neighbor from financial freedom and keeps them even from undertaking those basic services of citizenship required by the State. A monopolist of land, or anyone who is greedy for it, occupying more than they can efficiently use, represents a severe threat to the law itself for they would dispossess their neighbor of their birthright and exercise a greater authority in government.

Churchill's factory establishment example could be an example of the establishment any modest farm whose price of establishment increases as monopolization is undertaken to greater extents. What of the next generation of farmers whose families, having outgrown their estates, must colonize new lands and establish their own families? The new generation is crippled by the reduced availability of land, and the accompanying reduced availability of civil services. The more new farms established in a free economy, the lower the collective cost of those new farms: there will be competition for fence makers and barn builders, there will be numerous houses to divide the costs of electricity among.

When land is hoarded by large farms, an artificial shortage of land is caused, raising the costs of establishing farms and other businesses. When landlords hold onto land without using it, they cause an artificial shortage of land, making it more difficult for others to establish farms and other businesses. When governments make farming illegal, or otherwise limit the use of land through zoning, they cause an artificial shortage of land, further raising the costs of establishing business.

The example of the landlord who holds onto undeveloped land in a city is, in the end, not too dissimilar to the large farmer who, against the dire needs of their fellow citizens and their State, holds onto more acres than they need per-person in their family.

But here are Churchill's heroic words:

Unearned increments in land are not the only form of unearned or undeserved profit, but they are the principal form of unearned increment, and they are derived from processes which are not merely not beneficial, but positively detrimental to the general public.

Land, which is a necessity of human existence, which is the original source of all wealth, which is strictly limited in extent, which is fixed in geographical position – land, I say, differs from all other forms of property, and the immemorial customs of nearly every modern state have placed the tenure, transfer, and obligations of land in a wholly different category from other classes of property.

Nothing is more amusing than to watch the efforts of land monopolists to claim that other forms of property and increment are similar in all respects to land and the unearned increment on land. They talk of the increased profits

of a doctor or lawyer from the growth of population in the town in which they live. They talk of the profits of a railway, from the growing wealth and activity in the districts through which it runs. They talk of the profits from a rise in stocks and even the profits derived from the sale of works of art.

But see how misleading and false all those analogies are. The windfalls from the sale of a picture – a Van Dyke or a Holbein – may be very considerable. But pictures do not get in anybody's way. They do not lay a toll on anybody's labor; they do not touch enterprise and production; they do not affect the creative processes on which the material well-being of millions depends.

If a rise in stocks confers profits on the fortunate holders far beyond what they expected or indeed deserved, nevertheless that profit was not reaped by withholding from the community the land which it needs; on the contrary, it was reaped by supplying industry with the capital without which it could not be carried on.

If a railway makes greater profits it is usually because it carries more goods and more passengers.

If a doctor or a lawyer enjoys a better practice, it is because the doctor attends more patients and more exacting patients, and because the lawyer pleads more suits in the courts and more important suits.

At every stage the doctor or the lawyer is giving service in return for his fees.

Fancy comparing these healthy processes with the enrichment which comes to the landlord who happens to own a plot of land on the outskirts of a great city, who watches the busy population around him making the city larger, richer, more convenient, more famous every day, and all the while sits still and does nothing.

Roads are made, streets are made, services are improved, electric light turns night into day, water is brought from reservoirs a hundred miles off in the mountains – and all the while the landlord sits still. Every one of those improvements is affected by the labor and cost of other people and the taxpayers. To not one of those improvements does the land monopolist, as a land monopolist, contribute, and yet by every one of them the value of his land is enhanced. He renders no service to the community, he contributes nothing to the general welfare, he contributes nothing to the process from which his own enrichment is derived.

While the land is what is called "ripening" for the unearned increment of its owner, the merchant going to his office and the artisan going to his work must detour or pay a fare to avoid it. The people lose their chance of using the land, the city and state lose the taxes which would have accrued if the natural development had taken place, and all the while the land monopolist only has to sit still and watch complacently his property multiplying in value, sometimes many fold, without either effort or contribution on his part!

But let us follow this process a little further. The population of the city grows and grows, the congestion in the poorer quarters becomes acute, rents rise and thousands of families are crowded into tenements. At last the land becomes ripe for sale – that means that the price is too tempting to be resisted any longer. And then, and not until then, it is sold by the yard or by the inch at 10 times, or 20 times, or even 50 times its agricultural value.

The greater the population around the land, the greater the injury the public has sustained by its protracted denial. And, the more inconvenience caused to everybody; the more serious the loss in economic strength and activity – the larger will be the profit of the landlord when the sale is finally accomplished. In fact, you may say that the unearned increment on the land is reaped by the land monopolist in exact proportion, not to the service, but to the disservice done. It is monopoly which is the keynote, and where monopoly prevails, the greater the injury to society the greater the reward to the monopolist. This evil process strikes at every form of industrial activity. The municipality, wishing for broader streets, better houses, more healthy, decent, scientifically planned towns, is made to pay more to get them in proportion as is has exerted itself to make past improvements. The more it has improved the town, the more it will have to pay for any land it may now wish to acquire for further improvements.

The manufacturer proposing to start a new industry, proposing to erect a great factory offering employment to thousands of hands, is made to pay such a price for his land that the purchase price hangs around the neck of his whole business, hampering his competitive power in every market, clogging him far more than any foreign tariff in his export competition, and the land price strikes down through the profits of the manufacturer on to the wages of the worker.

No matter where you look or what examples you select, you will see every form of enterprise, every step in material progress, is only undertaken after the land monopolist has skimmed the cream for himself, and everywhere today the man or the public body that wishes to put land to its highest use is forced to pay a preliminary fine in land values to the man who is putting it to an inferior one, and in some cases to no use at all. All comes back to land value, and its owner is able to levy toll upon all other forms of wealth and every form of industry. A portion, in some cases the whole, of every benefit which is laboriously acquired by the community increases the land value and finds its way automatically into the landlord's pocket. If there is a rise in wages, rents are able to move forward, because the workers can afford to pay a little more. If the opening of a new rail-way or new tramway, or the institution of improved services of a lowering of fares, or of a new invention, or any other public convenience affords a benefit to workers in any particular district, it becomes easier for them to live, and therefore the ground landlord is able to charge them more for the privilege of living there.

Some years ago in London there was a toll bar on a bridge across the Thames, and all the working people who lived on the south side of the river had to pay a daily toll of one penny for going and returning from their work. The spectacle of these poor people thus mulcted of so large a proportion of their earnings offended the public conscience, and agitation was set on foot, municipal authorities were roused, and at the cost of the taxpayers, the bridge was freed and the toll removed. All those people who used the bridge were saved six-pence a week, but within a very short time rents on the south side of the river were found to have risen about sixpence a week, or the amount of the toll which had been remitted!

And a friend of mine was telling me the other day that, in the parish of Southwark, about 350 pounds a year was given away in doles of bread by charitable people in connection with one of the churches. As a consequence of this charity, the competition for small houses and single-room tenements is so great that rents are considerably higher in the parish!

All goes back to the land, and the land owner is able to absorb to himself a share of almost every public and every private benefit, however important or however pitiful those benefits may be.

I hope you will understand that, when I speak of the land monopolist, I am dealing more with the process than with the individual land owner who, in most cases, is a worthy person utterly unconscious of the character of the methods by which he is enriched. I have no wish to hold any class up to public disapprobation. I do not think that the man who makes money by unearned increment in land is morally worse than anyone else who gathers his profit where he finds it in this hard world under the law and according to common usage. It is not the individual I attack; it is the system. It is not the man who is bad; it is the law which is bad. It is not the man who is blameworthy for doing what the law allows and what other men do; it is the State which would be blameworthy if it were not to endeavour to reform the law and correct the practice.

We do not want to punish the landlord. We want to alter the law.

Yet, no matter how unintentional or forgivable the actions of the large farmers are, the interests of the government in deliberately dissuading small farmers is intellectually questionable and morally objectionable. Land is not capital: no one made the land, no one can own it. It is a

public resource upon which our democracy is founded, upon which the individual liberty of every human being is based.

The mistakes of the French Revolution courted by America and other industrialized nations, precedent for actions taken

In Rome, land monopolization was countered by a strict limitation on the number of acres that could be owned by any citizen. This amount varied by location, as some lands were more fruitful than others. While it is not ours to suggest land should be regulated by monopoly law in America, it does demonstrate that other nations, faced with a similar problem reacted by regulating the land market. Land is a necessary natural resource, and a public one too: nobody made the land, it belongs to no one in particular. The interests of the public lie in the good management of the land: upon the land our supplies of fresh water, air and other critical natural resources depend.

There have been instances in American history when the government has required of farmers actions in the name of the public health: shortly after the importance of sanitation was fully learned, in the 1930's the government Jefferson helped found would require sanitation efforts to control the manures produced by its human inhabitants[28] who had colonized public lands upon a ration system conceived by estimating how much land was required to sustain a family.

Though there have been more occasions when the government has not acted on the public's interests than when it has (a half-century after the sanitation reforms were enacted, Joseph Jenkins would pen his benchmark agricultural work *Humanure*, which is discussed more in the chapter of composting, that would allow the safe, infinitely more affordable and total sanitation of waste. Against this existence of this revolutionary improvement, the government idles as untreated sewage

[28] Dr. Charles O Collins of the Department of Geography, University of Northern Colorado, in Kenneth Jesseen's *Out the Back, Down the Path, Colorado Outhouses* describes the government's force in requiring private sanitation efforts to protect the public:

Many Great Plains settlers managed without a privy, counting on isolation for privacy and the natural environment to provide sanitation. Traditionally, people sought a secluded area where they tried to prevent odors by carefully selecting a different place each time. The folk association of odors with disease discouraged accumulation of wastes in a privy, or any location near the dwelling and promoted the scattering of human wastes where the "well known" cleansing properties of the soil, sunlight and rain (not to mention scavenging hogs) provided "natural" waste disposal...It should not be necessary to point out that such attitudes were more convenient in the eastern and southern states than on the Great Plains. However, pioneers brought their habits with them, and consequently turned to the wheat field, shelterbelt, pigpen or corral as an acceptable "privy."...

...Increasing population and a more enlightened attitude toward personal and community health promoted farm and village privies. Still, state or federal legislation was often necessary to assure that every Great Plains resident had access to a privy. Apathy sprang from ignorance, but there were those who opposed privies on philosophical grounds. Some males asserted that privies were strictly for women and children, and for an adult male to use them was unmanly. In a similar vein, a few "rural authorities" insisted that privies or water closets never be allowed inside houses as this was a sign of effeminacy.

streams into our rivers whenever it rains), this is no argument against upholding the interests of the public.

England during Tull's time was in a period of colonization and settlement, there was a surplus of unused land and the threat of monopoly simply did not exist; America in Jefferson's time was faced with a similar bounty. When Cobbett set forth his edition of the Horse Hoeing Husbandry, there was a real threat of monopolization and the corruption resulting from it.

The public lands of the United States were settled and colonized on a rational system wherein land was rationed and limited based on how much land was required to sustain a family in a Homestead Act; it is inconceivable that the modern monopolies were intended by the law. Likewise, it is inconceivable that the subsidy aid promised to poor farming families by Roosevelt would have been intended to augment the wealthiest farms as they push out the poor, smaller family farms.

The 18th Century French farmers were not forced by their government to adopt better farming techniques, though those techniques were as much for their private benefit as for the public interest. And later, in a famine-induced rage, these same farmers overthrew the government that did not secure their interests.

The dangers to our Republic aside, the obnoxious and intolerable theft of a citizen's birthright aside, the erosion of labor wages aside, should we enter into a more dramatically variable climate, as existed in Cobbett's time, it is in not only the public's interest but our species' to have an atomistic farm economy. As hard as the environment was to farmers in Tull's age and Cobbett's age, it is unlikely today's farmers will find the environment any kinder.

Rewarding farms for becoming large does not secure the public's interests: when large farms fail to produce a crop, no matter their available credit, they fail to feed the people who depend on them.

The crisis of the French Revolution was bred of an economy of low laborer wages and famine, the exact situation being staged today.

While we would not be so forward to suggest what our leaders should do to correct this dangerous threat to its law and the justice of their government, to suggest the painful and costly act of acquiring lands at market price and auctioning them in a new homestead act, and placing constraints on land ownership to prevent the same error from happening again, we will suggest what the small or new Tullian farmer can do against this injustice.

We do so not because we ourselves fail to trust our government to take the righteous course of action – no matter how hard – but because it is infinitely more practical for the farmer who would not trust the law to defend their birthright.

A small Tullian farmer can compete against larger competitors, against the undue difficulty

Can a small Tullian farmer compete against larger competitors?

We will trust there are sufficient resources of small lands remaining to sustain a new or small farmer but we cannot pretend that the monopolization of land, while not excluding a new or smaller farmer, does present undue difficulty – no matter how efficiently or profitably they can farm the land. It is difficult for small and new farmers.

Today we face renewed climate changes, political instability, terrorism, threats of natural and unspeakable human disaster, the need for financial independence, extensive corruption of both the citizenry and their government: many towns and cities no longer allow for a direct election of their Executive, who appoints Judges and draws election districts for Legislators.

Against these the Tullian farmer is armed well. Their farming is quickly established on rental lands, earns prodigious profits to afford them the enormous price of land, protects them somewhat against climate changes, and sets them on the path to becoming a land monopolist themselves. Yet it can do little against the political threats that daily increase. For this protection, they must seek the advice not of Tull, but of Noailles, Cobbett, Jefferson, Churchill and other defenders of our freedom.

Small farmers can band together in cooperation, forming corporate cooperative entities to give them the advantages of large farms. They may band together and establish townships and counties. They may unite, under the interests of a free market and free Democracy, to establish the good and just laws required to reestablish the honor of their nation, to fulfill the dreams of peace and civilization promised to them by a constant and plentiful harvest.

They may also perpetuate the evil and use their efficiency to monopolize land.

About Jethro Tull and his purpose in publishing his work

"Mine is the first book of Agriculture that has happened to by pirated, and upon first notice of it, I ought to have desisted because then I must be a loser by proceeding any further at the press. And I could have little obligation to a country whose laws did not protect me in the property of my labor and of that expense that is joined with it. The best apology I can make of my folly is that it is natural for the true parent rather to lose the property of his offspring than not to endeavor to preserve the life and wellbeing of it, though in the hands of his enemies." –Jethro Tull, Supplement of 1750

Before the work itself is delivered, we would trouble the reader with some words on Jethro Tull's family history and the historical context of the work to demonstrate their influence on the work's motivation, on the remarkable history of the work itself, its relationship to the strikingly similar Fukuokan agriculture developed independently in the 20th Century, and introduce the purpose and scope of our improvements to the work.

About the Editors

Our qualifications to aspire to improve such a work are few. We are farmers who profited from Tull's work and theory to understand its potential for improvement. We studied agriculture at Colorado State University, but never obtained more than a Bachelor's degree in Agricultural Science there.

Yet we defend our arrogance it was Tull's intent that even a common farmer, less trained in science than we have been, with fewer years of experience than we have had, should be able to improve the art as well as any learned person might and, with this in mind, few people are more qualified than those who both dearly love the science of agriculture and Tull's purpose in undertaking this work.

For our part, it has been a majestic enterprise, not for the glory of Tull, but in the service of the God he worshiped; the self-same selflessness that guided Tull, Monceau and Cobbett has guided our work and sustained us as we spent our years in perfecting his method a little more. No doubt there is still room for more improvement, no doubt those with more learning than us could improve it further, but with few learned Doctors lending their skills to empower the most needy of the

farmers, we were compelled by need to have assumed perhaps more responsibility than we had otherwise qualified for.

Praise for loyal learned men and women and their institutions of learning, rebuke for treacherous, corrupting, lying cowards

We wish to recognize first our deep set respect for those institutions of learning that would advance agricultural knowledge, and the Doctors within them. Though Tull is at times harsh with men of learning, and we sometimes appear to be more so, please note also the respect and reverence both we, Tull and previous editors have paid to virtuous men and women of learning.

Both the original author and those subsequent editors are harsh only out of respect for the institution that is betrayed through the horrific incompetence, malicious exclusion and supreme failure of some of those institutional members have achieved; that we place heavier blame upon the Doctors than upon the amateurs should come with little surprise and require less explanation.

Failure in the responsibility of those who would lead with the light of science, betrayal by scientists; an explanation of our high expectation for scientists

The light of science is not a guarded flame, but one which is shared and should illuminate the world. Those who place roadblocks before those with less training or qualification betray their sacred obligation to the flame of Truth. Indeed, it is better to drown in ignorance than to prevent or discourage anyone from pursuing the science that illuminated your understanding of the world because, in doing so, you will limit your own understanding. Those journals, those Universities, those associations of esteemed accredited men and women who would exclude, without regard to the merit of the work, those without the accreditation of association attack the very root of the tree of knowledge; those who would blindly assail the amateur like Tull undertake a great dishonor and disservice.

There was a proud time before Universities and journals, and Jethro Tull lived to see their rise to prominence and leadership in society. Tull witnessed the noble birth of a popular scientific revolution and the development of institutions of learning as societal leaders; Tull, more than any other, has right to complain against those charged with fanning the flames of science keeping the cold masses from the warm fire or, far worse, spreading ignorance and fear instead of the righteous hope and knowledge.

And how can a populace, so unarmed by the tools of reason and logic, defend itself against these lies?

Today, as Tull was, we are at a dangerous pass through which the advance of science will be sorely tested. As illiteracy rates climb, as adults fail to understand even basic mathematics, as reason and logic become mysteries of wonder, we enter upon a new dark age. Worse, the very English language itself is lost in a maze of analogies and suppositions (like, well...you know) wherein it falls to a shameful death through the emotional hieroglyphics of emoticons so that, in its present state, people are barely able express the subtle reality of the rationality and reason that they are at the point of forgetting :* (

[To those who might be happily unaware of what the previous emoticon means, it is used to depict a crying face by orienting the view clockwise]

The toleration and even encouragement of anarchism and tolitarianism, despotism and nepotism, materialism and zealotism, favoritism and all the isms of a Republic on the road to hell and tribulation is now unconquerable through rhetoric, for those who subscribe to the horrid ideas do so because of some initial inability to reason. Once convinced, they are not apt to change: to reason through their bad beliefs the first time was too much work to be carelessly repeated because of some counterargument that might be presented.

And what of those scientists on whose watch the light of science fades? Devoured by the disgusting arts of war and corruptive business greed, they slaughter millions of innocents both in the battles of the nations and in the wars of commerce.

> *It is strange that no author should have written fully on the fabrication of plows! People of the greatest learning have spent their time in contriving instruments to measure the immense distance of the stars, and in finding out the dimensions—even the weight—of the planets; they think it more suitable to study the art of plowing the sea with ships than the tilling the land with plows. They bestow the utmost of their skill, learnedly, to pervert the natural use of all the elements for a destruction of their own species by the bloody art of war: some waste their whole lives in studying how to arm death with new engines of horror, and inventing an infinite variety of slaughter, and think it beneath people of learning (who are the only people capable of doing it) to employ their learned labors in the invention of new (or even improving the old) instruments for the increasing of bread!*
>
> —Jethro Tull

Our nation, founded by the students of the same scientific revolution, will find no flame of liberty to ward off the monsters of this rising night. And there they loom: the technological wonders of our grandparents and parents, wrought by men of learning bent upon the destruction of their species.

The sad irony of that Silent Spring when Atoms for Peace and Invisible Greenhouses boil the Free Seas will be that there will be few who understand exactly what is going on any better than the innocent animals who are wastefully slaughtered. Those men of learning who Tull derided for arming death with engines of war have sown bitter fruit, and the poisonous thorns of sloppy science undertaken by humanity's loyal defenders even now weave their crowns upon our humanity. We die, not a martyrs death, neither a hero's death, but a shameful death indeed.

Truly, science is betrayed by those with whom we farmers would share our bread; it is betrayed by every man and woman who would rather lend their artistic and scientific talents to the destruction of the world and neighbors they enjoy.

If our words in this book are harsh for these traitors, it is because we place our hopes in those loyal men and women within the crumbling institutions of learning to stand up in defense of Truth. Should they rigorously defend Truth against the onslaught of corrupt and incompetent research through vigorous debate and experimental demonstration, there would be little reason for us to do so through the publication of this work. Should they stand up and disarm those wielding the terrible weapons, should they press forward for peace, should they empower their neighbors with the scientific method and improve agriculture, we would not need to try. We have a right to outrage: for we looked in vain to their leadership.

Yet do not forsake hope: it is yet possible to cross the gap and see pleasant valleys beyond the passes of fear Science now traverses, but it will require great sacrifice.

Some who have read this work before its publication suggested we omit our discussion with Dr. Warkentin, or offer an apology to him. We will not do so. The shame is not upon us for investigating his claims and finding them full of falsehood, the shame is not upon us for our strong and (perhaps) disrespectful language. The shame is upon him for holding a Doctorate we are ourselves not worthy of and abusing its credibility through treacherous claims.

What is the object of scientists like Dr. Warkentin? For that matter, what are the objects of those scientists who take money to prove an industrial product safe, effective or useful, all those scientists gain who argue for the use of poisons in our water, poisons in our air and fearful weapons of mass destruction? While the object of the later is clearly greed and perhaps may be forgiven when all is said and done, the objectless desecration of the institutions of science that bestowed upon the likes of Warkentin their Doctorates is unquestionably damning. For, while one sells Truth too cheaply, the other casts it away without any consideration to its value at all.

Let us not be misunderstood. There are many more like Dr. Warkentin; our issue is not with him alone, though he is perhaps a good example of the negligent, unthinking, unintentional desecration of science. His fault lies mainly in his criticism of Tull, a subject of this book which we have investigated, and in the interests of

Reason to hope against an unscientific age

As we enter into what Dr. Richard Feynman, one of the greatest physicists of any age, described as an age without science – an "unscientific age" – we hold hope that science will rise again. Look at the crown of thorns, the death that awaits Science and do not lose faith! The immortal soul of Truth is invincible, though everybody in its service dies, every letter in every book is blotted out by time, the method of Science itself is can be destroyed corrupted and forgot... only to be rediscovered later.

Tull's work nearly died such an ignoble fate. Today it rises again. Though the man himself is dead, even if his work followed him to the grave, it would inevitably be rediscovered by anyone willing to take up the torch of science and follow the paths of logic and reason. Logic and reason would lead them to reinvent the seed drill, the disk plow, to rediscover plant physiology and ecology, to rediscover how to preserve and trade grain, how to undertake any of the miracles that Tull did while serving science.

The advance of agricultural science since Jethro Tull

The science of agriculture, begun by Tull's efforts, has progressed considerably since Tull's first works. However, with few exceptions, Tull's initial endeavor was so scientifically sound that it remains not only relevant, but insightful even today.

The few places in which Tull's science failed him (usually due to the incomplete data resulting from the ancient technology with which he worked – though he did falter several times for other reasons) we have updated, but in doing so, we recognized the supreme skill by which Tull presents data in a way to account for his own inability to perceive all data.

The few places in which Tull's science failed him are in this way made into even fewer places in which Tull's science fails his student. We have learned from the master himself, and have, in every circumstance, attempted to replicate his sincere dedication to presenting facts, and the bounds under which they are known to be true.

Equally important to Tull's student is the way in which Tull does not present dry facts and figures, but illustrates his method of obtaining them in a way that allows his student to not only reproduce his learning, but surpass it. The student understands not only how to farm better, but how to advance the science of agriculture.

Lacking entirely from Tull's work is commentary on animal husbandry. This was due to Tull's untimely death, and we have inserted some notes on animal production. In doing so, we emulated Tull's approach to crop production to allow the student to surpass our own understanding.

About Jethro Tull



The historian Norman Hidden spent some effort on researching Tull in his authoritative work, *Jethro Tull I, II & III*, published in the *Agricultural History Review* (37, 1989).

He proposes a theory of three Jethro Tulls: uncle, nephew and grandnephew, the grandnephew being the author the Horse Hoeing Husbandry. "Although Jethro Tull has been recognized as an important innovatory figure in agricultural methods in the eighteenth century, little has been written concerning his origins and social background; and much of that is either vague or inexact. From genealogical and other research, new information is provided concerning the family background of Jethro Tull. In particular the three Jethro Tulls who overlapped in time and place (especially with regard to Prosperous Farm) are distinguished. Some revision is suggested in the date of Tull's commencement at Prosperous Farm and of his journey to the continental vineyards. This and other additional background information throws light both on Tull's personality and behavior and on his need to innovate in order to convert Prosperous from sheepdown to arable."

"An article written by one DY of Hungerford and published in the Gentleman's Magazine in 1764 [pages 522 -526]. The identity of D Y is not known, but he claims to have been 'personally acquainted' with Tull and, if the ascription 'of Hungerford' is true, he lived in the same parish and was therefore in a good position to know something of a personal kind concerning the subject of his article. Nevertheless, there are many details which he takes on trust from the scattered autobiographical details given by Tull himself."

Hidden also refers to Earl Cathcart's article, *Jethro Tull*, (JRAS, 3rd series, II) published in 1891 for the Royal Agricultural Society. This article bases itself on the diary of Cathcart's ancestor, an earlier Earl Cathcart who befriended and encouraged Tull during his lifetime. On these three sources – Tull himself, D Y of Hungerford, and Earl Cathcart – all subsequent biographies have based themselves, adding thereto little of consequence."

Hidden says that "Some of the main confusions and uncertainties concern Tull's parentage, his father's place of origin, his social and financial standing; the date and place at which Tull himself commenced farming; the date at which he removed from Howberry to Prosperous Farm in Shalbourne; the true date of his extensive tour abroad to Montpellier and the French vineyards; and even the exact date and place of his death."

We will now quote liberally from Hidden.

The Dictionary of National Biography states that Jethro Tull was born at Basildon in Berkshire in the year 1674, the son of Jethro and Dorothy Tull. And indeed there is an entry in the Basildon parish register recording a baptism on 30 March 1674 which confirms this. After this date, however, there are no further entries in the Basildon register which might indicate that the family were settled in the parish and thus the probability that young Jethro spent his boyhood there.

G E Fussell in his Life of Jethro Tull is aware of this difficulty. 'How the family became connected with Basildon was not known in 1889' (presumably the date of publication of the DNB article), he writes (G E Fussell, Jethro Tull his influence on mechanized Agriculture, Reading, 1973).

In fact, however, the connection with Basildon is explicable, and in what is the most likely way. It was in Basildon in June 1672 that Jethro Tull married Dorothy Buckeridge. The Buckeridges were a Basildon family and Basildon was the bride's parish. A search of neighbouring parish registers reveals that Jethro and Dorothy had a daughter, named Dorothy, baptized in the parish of Bradfield on 5 February 1676. Bradfield is the parish immediately south of Basildon; and this rather than Basildon, was the home of the Tulls. The next baptism we have for a child of Jethro and Dorothy Tull, however, is in a parish as far removed in Berkshire as it was possible to be. This was the baptism of Elizabeth, daughter of Jethro and Dorothy Tull, at Shalbourne 14 April 1679 (Berks RO, Basildon Parish Register)

Shalbourne was the site of Prosperous Farm; it lies at the extreme southwest of the parish of Hungerford and is partly in Wiltshire and partly in Berkshire. The question arises as to what was Tull senior's connection with Shalbourne at this date, and whether he was farming Prosperous Farm there. Indeed Fussell asks whether the connection may not have been even earlier, pointing out that the 1664-6 (sic) Visitation of Berkshire mentions a Jethro Tull of Shalbourne 'who married Mary, daughter of one Farmer of Cholsey, whose Christian name is not stated' (Berks RO, Basildon Parish Register). But it is stated, revealing that Fussell had not consulted his primary sources. The Visitation shows that Jethro Tull of Shalbourne was the son of Giles Tull of Midgham, Berks; that he had an elder brother James of Bradfield, Berks, and a younger brother Giles; and that he married Mary daughter of Jeffery Farmer of Cholsey, Berks. That these facts are correct is certified by Jethro Tull himself (Visitation of Berkshire 1665/6. Harleian Soc, LV I, p 297.)

The Victoria County History of Berkshire confirms this marriage, indirectly, by its entry concerning the adversion of the church of Cholsey, possession of which was shared in 1682 by Mary, 'daughter of Geoffrey Farmer and wife of Jethro Tull (Victoria County History, Berks, III, p 302.)

The possible awkwardness of a daughter born to Jethro and Dorothy Tull in 1679 (Wilts RO, 534/1 Shalbourne Parish Register) and a Jethro Tull with a wife Mary in 1682 seems to have raised no queries from the

biographers of the son of Jethro and Dorothy. One would expect them to have searched for a burial entry between those years which would confirm the death of Dorothy. In such searching they might have discovered, but obviously did not, that there exists a foot of fine in 1678, in which Jethro Tull and his wife Mary sold land in Hungerford, Inkpen and Shalbourne to Sir William Jones, Attorney General (Public Record Office: CP2512/29.-3o Charles II, Hilary term.)

Only two conclusions seem to present themselves: either Jethro Tull was a bigamist or there were two Jethro Tulls, both associated with Shalbourne. Still further search uncovers a case in Chancery in 1678 in which Jethro Tull was a defendant in a suit brought by Frances Farmer widow of Jeffery Farmer, in which a copyhold in Cholsey was involved and concerning the administration of the estate of the late Jeffery Farmer (PRO. C22/249/5).

Depositions in yet another suit claim that in January 1674 an agreement or treaty was made between Griffith Jones of Radnorshire, Wales, and Jethro Tull of Cholsey, Berks, for a marriage to be solemnized between Jones's son and Elizabeth Goddard, daughter and heir of Vincent Goddard, late of Howberry, Oxon. Esq. deceased, Jethro Tull having married Mary, Elizabeth's mother (PRO, C5/169/38.).

Clearly, if there are two Jethro Tulls at this time, one married to Dorothy Buckeridge and one to Mary Farmer, both having associations with Howberry as well as with Shalbourne, it becomes difficult to be certain of the exact origins of Jethro Tull the agriculturist. And if the Jethro Tull of Cholsey married Mary Farmer how is it he is now revealed as married to Mary Goddard? The answer to this is fortunately simple. Mary Farmer first married Vincent Goddard; and subsequently, following Vincent's death (PP, O, PCC Will, Vincent Goddard 1657), is she became the wife of Jethro Tull. For the purpose of this article it may now be convenient to label Jethro Tull who married Mary Goddard as Jethro Tull I and Jethro Tull who married Dorothy Buckeridge Jethro Tull II. Jethro Tull the agriculturist will then be Jethro Tull III.

Which of the Jethros I and II was the Jethro Tull who was holding Prosperous Farm in the years prior to its occupation by the agriculturist Jethro Tull III? Deeds in the Wiltshire Record Office connect Jethro Tull II and his wife Dorothy with Prosperous Farm in 1686. (Quoted by Fussdl, op cit, p 21.) Deeds formerly in the Berkshire Record Office but now in the Wiltshire Record Office relate to a Jethro Tull in the area in 1674 and earlier (Wilts P,O, 1883/127.). The biographers of Jethro Tull the agriculturist (Jethro III) have simply merged the two men into one. They have not only missed details in local parish registers (more accessible nowadays than in theirs), but they seem to have been unaware of the rich source of material in the records of the court of Chancery which concern Jethro Tull I, II, and III.

Deposing in a Chancery suit which occurred in 1676, Jethro Tull I describes himself as of Cholsey, Berks, gent, aged 60 or thereabouts. He had been employed by Thomas Hussey senior in receiving and collecting the rents and profits of Hussey's estates In Hampshire, Berkshire and Wiltshire for nearly twenty years before the latter's death, (which occurred in 1657).

He continued in this capacity during the lifetime of Hussey's son, Thomas Hussey junior (who died in 1661) and again for his heir William Hussey, who in 1668 relinquished the estate to a group of trustees headed by Sir Robert Mason. Tull was employed by them in a continuing capacity until about 1673 (PRO, C24/1012 pt 1.).

In the management of these estates Jethro Tull was the one continuing element, a trusted agent who served one master after another. His indispensability was recognized by substantial annuities bequeathed in the wills of both Thomas Hussey senior and Thomas Hussey junior. Business transactions, including the sale or lease of properties, were carried out by Tull on behalf of his employers. He was the centre of a whole web of estate affairs; the network was complex and intricate and its management full of difficulties. The difficulties arose from the fact that the ancient family of Hussey lived above its income, as the suit Elwes v. Wall makes plain. According to Jethro, Thomas Hussey senior was indebted at the time of his death to several persons for considerable sums of money upon mortgage bonds and otherwise amounting to £23,000 and about £1000 in addition on his own account (PRO, C24/1012 pt 1.). "Jethro's account is

honest and lucid. The trustees 'could not raise money out of the estate to pay the testator's debts, annuities and legacies as fast as they were demanded or called for and to pay fines for renewing leases, but were forced from time to time to prevent suits or damage to the estate to take up several great sums of money upon their own bonds or security at interest for payment of the said debts, annuities or legacies." It would seem that the affairs of the trustees and of Jethro himself, their friends and acquaintances all became involved in the affairs of the Hussey estate (P, Spalding ed, Diary of Bulstrode Whitecocke [in preparation OUP].) as lenders or borrowers or sureties. The juggler given the task of keeping all these balls in the air was Jethro Tull. The principals who employed him quarrelled among themselves and were unwilling or unable to adjust themselves to the growing crisis.

The point was reached where the profits of the estate were not sufficient to pay the interest and brokerage of the debts and the inevitable crash came in or about 1673-4. Tull, whose hand was in everything, went down first. Sir Bulstrode Whitelocke, Cromwell's former ambassador to Sweden, who had been encouraged by Tull (as agent for Hussey's trustees) into the purchase of Chilton Park and the manor a few years previously, notes in his diary on I May 1674: "More [news] of Mr Tulle's being broke." It caused trouble for Whitelocke for he, too, had been a surety in one of Tull's deals on behalf of the Hussey estate.

During the period of collapse Tull's own lands were being sold off in a desperate attempt to bring the financial crisis under control. In 1674 Tull signed a release of Anvilles Farm, and another of Helmes Farm to Sir William Jones (Wilts P,O, 1883/1'7.) In 1677 he released his rights in Helmes Heath to Sir John Elwes, one of Hussey's trustees, and in 1677/8 he released to Sir William Jones all his estate in Old Anvilles. These properties were all in the immediate neighbourhood of Prosperous Farm, and it would seem that Jethro, by various purchases or gifts from the Husseys, had been building up a small but conglomerate estate of his own in an area to which he may have had a special attachment. Any such ambition was now dashed.

When news of his misfortune broke everyone turned on the hapless agent. He was involved either as a principal or as a deponent in a succession of law suits (PRO, C22/803/50;C'2/1ot/16iC22/' 49/5;C24/IOI';C5/169/38.) and for the remainder of his life Jethro Tull I had to dodge his creditors. One of them pursued him from Wales to Cholsey where he found only his wife Mary. Mrs Tull told the weary seeker that 'her husband had not been there once for a long time before, neither could she tell him where to send unto him'. Another deponent in the same suit asserted that 'it is commonly reported that Tull is far indebted and engaged deeply to many creditors that he hath by reason of his own debts and suretyships for others passed and conveyed all his estate to some trustees under colour of bargains or privately that thereby he might avoid the payment of his debts ... it is also commonly reported that he doth abscond and hide himself in some privileged places (or places said to be privileged) from arrest lest he should be arrested (PRO, Czz/465/8.).

In 1688/9 Tull was in Midhurst, Sussex (PRO, Cz4/1la3.) and there he died, being buried on 3 September 1691. The burial record is taken from a typed transcript made by W H Challen and, typical of the confusion which surrounds and clings to the name Jethro Tull, it has been mistranscribed as Jethro Full! (W H Challen, Typescript, vol XII. Guildhall Library, London).

II

His busy, active life may seem to have ended in failure. But he never gave up his ambition to establish a Tull estate in that hilly corner of Berkshire adjoining the lands of his former employers. Somehow he contrived to squeeze out of his losses a farm in the area which he boldly called (or which by amazing chance was called) Prosperous. He was able to do this by transferring the farm to Jethro Tull II before his creditors could get at it. A letter written by Jethro I to

Jethro II and dated 25 May 1680 says "I owe you for my own dyett [diet] and for nay horse ever since you came to Prosperhouse" (PRO, C22/940/2 4,) seems to substantiate the deposition which referred to his use of "trustees" to save some at least of his estate from the Tull/Hussey creditors. The letter (particularly when linked with the baptism in Shalbourne in 1679 ofJethro Tull II's daughter Elizabeth) makes it clear that Jethro II had settled into the property; and the acknowledgement by Jethro I of his debt for board and lodging suggests that he had granted the estate to Jethro II more fially than if he had appointed him as a nominal trustee only.

The use of the name Prosperous at this early date, long before the agricultural innovations of Jethro III, shows that the farm's name did not derive (as some may think) from the youngest Tull's success but was already in existence. The earliest use of the name I have been able to find is in a document of 1677 when Jethro Tull I is described as of Prospers farm (Wilts P,O, 1883/127.). It is certain that the farm, as such, did not exist before the time of Jethro Tull I. He seems to have created it from bits and pieces of land lying in and between other farms in the area, such as Hehnes, Anvilles, Old Anvilles, and Hehnes Heath. The latter was an area which had been subject to constant enclosures (Berks RO. H/M 5) and one must suspect that Prosperous may have in part owed its origin to one or other of these enclosures.

Jethro III says that the farm was "cut out of the skirts of others and a great part of the land was formerly a sheep down," and elsewhere in his book he says that Prosperous was first made into a farm "about seventy years ago," a statement that takes it back to the time of Jethro I (Tull, op cit, pp 214, 386.).

Since Jethro Tull I granted Prosperous Farm to Jethro Tull II, how close was their relationship? Although all previous writers have confused (or ignored) the relationship, usually considering Jethro I and Jethro II as one and the same man, the answer is quite simple. Jethro Tull I was the brother of James Tu11 of Bradfield, and James was the father of Jethro Tull II (PP, O, C22/920/24.) The two Jethros, therefore, were uncle and nephew. As it was the uncle who had married Mary Goddard and the nephew who had married Dorothy Buckeridge itis clear that the father of Jethro Tu11 the agriculturist was Jethro II.

The family was evidently very close and in a deposition in 1698 young Jethro Tull III, then aged 24 and at Grays Inn, testifies on behalf of his father (PP, O, C22/920/24). Also deposing is another James Tull, brother of Jethro II, who states that his uncle [Jethro I] "did possess and live in a farm called Prosperent (?) farm in or near Shalborne or Bagshot and worth about £100 p.a., part freehold and part leasehold, and another farm of about £30 p.a. in or near Bagshot or Shalborne, Berks for about seven or eight years of his said uncle's life," and he believed his brother [Jethro II] had received rent from it ever since Jethro I's death. The last time James Tull had seen his uncle was at the Rose and Crown in the precinct of Whitefriars in London not long before the latter's death when his uncle told him that he had made over certain farms and premises to his nephew [Jethro II] in trust for the payment of his debts and seemed to complain that Jethro II had paid little of them.

Jethro II continued to hold his estate at Howberry throughout these crises. In 1691, about four years after he had acquired Howberry from Edmund Gregory (an associate of Jethro I), he was involved in a law suit concerning the rent charges and taxes on the property (PRO, C22/96/3). This is the first sign of his growing financial problems. It is also the year in which his uncle Jethro I died. Sheltered hitherto from legal and financial problems by his uncle's ingenuity and wide-ranging contacts, Jethro II now began to be plagued by lawsuits which had reached a peak in 1695 and in which his family affairs were exposed in all their shakiness (PRO, C22/920/23). The financial problems which brought down Jethro I were now close to bringing down Jethro II too. This was during those years when his son Jethro III was leading, successively, the life of an undergraduate at Oxford, a student of Grays Inn, and a young man about town in London. The fall of his great uncle Jethro I would have been ancient history but the effects of it were continuing and the financial predicament in which this involved his own family cannot have been but embarrassing, perhaps distressing, to a young man in a family so closely knit that the name Jethro (meaning in Hebrew, ironically,

"abundance") was passed down for three successive generations. The sudden reversal of the Tull family fortunes and its continuing reverberations may be the circumstances to which Jethro III referred when he wrote that "accident, not choice, made me a farmer, or rather many unforeseen accidents" (Tull, op cit, p xi.).

In 1697 Jethro Tull II explains that he, his father James Tull, and his uncle Jethro I had had "many dealings together and [had] been bound for one another in several bonds." (PRO, C10/353/52). When James died, he appointed both Jethro I and Jethro II as his executors. But it was Jethro I who undertook the administration, Jethro II then 'being a young man and but little acquainted with business. Jethro II states that his uncle had satisfied all the debts owed by James and discharged all his bonds. He claims that the suits brought against him now were merely vexatious and that his time and money were being exhausted by his "being forced to defend himself against a multiplicity of suits and be put to the charges of bringing his evidences often times to the same matter at law." A year later there were no less than four suits pending which involved Jethro II (PRO, C22/920/34). Among the allegations made in the case in 1697 was one that Jethro II had undertaken to "pay all his uncle's [outstanding] debts and on that condition got all the estate from his said uncle in his lifetime."

III

Biographers of Jethro Tull III seem to have been unable to discover the date of his father's death. The actual date is of some moment in establishing when Jethro III may have inherited his father's estate in Howberry (and also the freehold portion of the estate in Shalbourne). It is possible that the estate, or a portion of it, was made over to him and his wife upon his marriage in 1699. The leasehold portion of the Shalbourne estate had been made over to him in 1704. (Quoted by Fussell, op cit, pp 21-22) This transfer (a lease having been previously held by his father dated 1686) has led some biographers to assume that it was in this year 1704 that the father died. This was not so: Jethro Tull II died in 1713 (PRO, CI H975/2).

Does the lease of 1704 mean that young Jethro began to farm Prosperous at that date while his father continued at Howberry until his death in 1713? The Dictionary of National Biography commences him at Prosperous in 1709, though for no given reason. No further reference has yet been found of Jethro II at Prosperous later than the 1686 lease; but there are various references to him in Howberry from 1688 onwards, corresponding with the suggested date of his acquisition of the farm at Howberry. The new property there would certainly have taken up his time and energies. It was quite natural, therefore, that from Michaelmas 1686 to September 1691 Prosperous Farm should have been leased to a local tenant farmer named Smith, a lease which was then extended for at least another two years (PRO, C10/353152). It seems unlikely that the occupation of Prosperous Farm by Jethro Tull III would have been later than the 1704 lease, and his management of the farm might have been even earlier. If it is true that Jethro began his agricultural experiments at Howberry it seems that they must have been carried out between 1699, the date of his marriage, and 1704 when he and his wife acquired the new lease at Shalbourne. If the experiments did indeed cause hostility in his father's main estate at Howberry, this could well have been a cause for the father to feel the need to remove the son to another area where he could begin afresh. On the other hand there is a local tradition that Tull's seed drill was first used at Prosperous Farm. The claim was made by a later owner of the farm, Lt.-Col Wills, who showed the broadcaster-journalist Ralph Wightman the very pit or well into which, he claimed, the villagers had pushed the hated drill, having first smashed and broken it (Ralph Wightmau, Rural Rides, 1957 p16.).

There has been much speculation concerning the date of Jethro Tull III's journey to the Continent. Fussell gives April 1711 as his date of departure, basing it on Tull's own statement, "and he is most likely to be correct, although memory is apt to play a man false" (Fussell, op cit, p 20).

The Dictionary of National Biography dates his departure similarly and gives his return as in 1714 (Dictionary of National Biography), article on Jethro Tull). If either of these statements were correct, one would wonder at the baptism on 13 October 1713 at Shalbourne of Tull's daughter Sarah (Wilts RG, 534/1, Shalbourne Parish Register). However, a different set of dates which makes much more sense is thrown up by the information given in yet another Chancery case in which Jethro III's brother-in-law states that Jethro, being seized of the Howberry estate in 1713 "and being in a very ill state of health was advised for recovery thereof to travel to Montpellier beyond the sea, which he accordingly did, but before he proceeded in his travel he made a letter of attorney empowering his wife Susannah to deal with his estates" (PRO, C1 1/1242/16).

Both parties in the case agree that Jethro set out for abroad at the beginning of the year 1713 [i.e. probably in April] and it is clear that he was out of the country before 6 July when his wife made some sort of agreement about the letting of his Oxfordshire estates. Both parties agree that Jethro returned in 1715.

While he was abroad two events occurred which he may or may not have expected when he set off and, if his health was bad, may not have been informed about. One was the birth of his daughter Sarah. If Tull left the country in April 1713 it is possible that he would not have known of his wife's pregnancy, which at the beginning of that month could have been of only a two-month period. The second event was the death of his father Jethro II. This was either in September 1713 or in March 1714: two different dates were provided by his in-law relatives in contention concerning his estate (PRO, C11/975/2). The Crowmarsh Gifford parish register, damaged by fire and incomplete, gives no record. Whatever the circumstances, a considerable burden must have fallen on Jethro III's wife Susannah. Susannah had married Jethro on 26 October 1699, according to Earl Cathcart (Cathcart, op cit.). The place of marriage is not given by Cathcart, but Fussell states that 'it may be assumed that it took place in London'. The assumption is made, presumably, to suit Fussell's account of the life of a young bachelor of means and status living there. It is a mistaken assumption: search of the parish registers of Burton Dassett in Warwickshire, where Susannah's family resided, reveals that the marriage took place in that parish (Warwickshire RO, DR/292/1.). The Smiths were a substantial yeoman family and it may be that young Tull, rather than leading a life of leisure and fashion in London, was sufficiently affected by his family's financial misfortunes to seek out a suitable provincial bride.

According to Tull's will he was survived by a son John and four daughters (PRO, PCC Will, Jethro Tull 1741). The date of John's birth is not known, but it must have been before 10 April 1704 since Jethro's son John is one of three lives on which the 1704 leasehold of a portion of Prosperous Farm is based. Shalbourne parish register records the baptism of Mary daughter of Jethro and Joanah Tull 2 March 1711 and Sarah daughter of Jethro and Joanah on 13 October 1713. Since all other records refer to Susannah, is this yet another example of the confusion into which the personal details of the Tulls' lives have been allowed to remain?

IV

The discovery of so many records containing miscellaneous information previously unknown concerning the Tulls I, II, and III has resulted also in unearthing a few items which, by alluding to farming practices by the two earlier Tulls, may throw a little light on the sort of family agricultural background from which the younger Tull developed.

When Jethro I was negotiating a marriage settlement in 1674 between Griffith Jones and his step-daughter Elizabeth Goddard, one of the items he insisted on having inserted into the treaty was that Griffith Jones senior should make a watercourse in his lands in Radnorshire which were to be settled on Griffith junior (PRO, C5/169/38), What the exact function of the watercourse was is not stated, but clearly it was designed for the improvement of the estate; and Griffith Jones complained bitterly that it had cost him some £400 to make.

Of greater interest are the details of Jethro II's conditions in leasing Prosperous Farm to John Smith in 1686 and his complaints concerning the tenant farmer's failure to comply with them. The bill and answer to this suit (dated April 1697) are contained within the documents which relate to another suit of that year (PRO, C10/353/52,). As the lease and its continuation expired in September 1693 it is difficult to know why Tull waited another four years before bringing his suit. It may be that he was desperate for the money owed to him by Smith. It would be interesting to know also what happened to the farm after Smith quit the tenancy in 1693.

The lease was drawn up in writing on 1 July 1686 and was to commence at Michaelmas next and to last for five years. Subsequently this term was extended to an amended rental for another two years. It was a condition that, on expiry of the five-year lease, the tenant should leave the ground well planted with clover grass 'as he had found the same' and to leave all the straw and chaff from the last year's crop.

When Smith entered upon the tenancy there were eighty acres or more planted with clover, but when he left there were only a few acres so planted, 'neither did he leave any straw and chaff or firewood'. Moreover, Smith was over £300 in arrears of rent.

Smith of course denied most of this. He stated that there was very little meadow ground in the farm, so little that Tull allowed him a £5 deduction from his annual rent to buy hay "and to preserve the timber on the estate did allow the defendant 40 shillings p.a. in lieu of plowbote and carthote." The area of the farm had been estimated at 300 acres and Tull had agreed to allow seven shillings per acre for any acreage below 300. Smith claimed that it was twelve acres less. He reckoned that he lost about £100 as a result of his five-year rental and he agreed to a further two years rental at a reduced rent. An additional complaint by Tull was that the hedges around the copses had been broken down, thus letting in the cattle which cropped the undergrowth, "all the young shoots and germms of wood." Smith admits this but says that the damage had been done by others.

When Tull agreed to abate Smith's rent after the fifth year he seems to have taken into account Smith's continual complaints 'of the hardness of his bargain, the badness of times, and the cheapness of corn'. In addition Smith had found taxation heavy and had had soldiers quartered upon him. Whatever happened to the farm between the time when Smith finally quit in 1693 and Jethro Tull III was assigned a lease in 1704 we do not know. Nevertheless the case just related gives us some idea of the circumstances of the farm which he inherited and a foretaste of some of the problems he would be likely to encounter in times that were bad for farmers and on land which was far from ideal.

In addition to a picture of the farming practice which Jethro III inherited, the Tuli v. Smith case illustrates Jethro's statement about Prosperous Farm that "every farmer on the old system that has rented it since it was first made into a farm, has either [gone] broke or quitted it before the end of his term" (Tull, op cit, p 386). Interesting as the Tull v. Smith case may be in showing the farming practice of Jethro II, there is another case which illustrates the practice of Jethro III in the very year of his momentous departure abroad, that is, before he comes back with his observations of the French and Italian yard tillage which led to his most important conclusions. In 1713 an agreement was made by Jethro's wife Susannah on his behalf, leasing an estate in Oxfordshire to a tenant farmer (PP, O, C10/1242/16). This agreement contained a clause whereby the existing tenant in his last year" was not to feed the field after he had cut his grass and he was to spend all his straw now in the barns, in the backsides and yards, and the straw thus growing or to grow, and the dung thereof made, and also the dung now laying in the backside [of the premises] and there leave the same" for the use of the incoming tenant. And the incoming tenant "likewise, in his last year was to spend all the straw on the premises and the dung thereof made, to lay on the same, except for the last year's dung, which he is to leave for the use of Jethro Tull."

After four years, and following Tull's return from abroad, the new tenant wished to exercise his option to quit and planted "grass seed called clover or St Foyn on twenty acres with his last crop of corn." It seems clear that, whatever

Tull's views on the use of dung may have been following his return from the Continental vineyards, he considered its use necessary at least up until the visit abroad he made in 1713-14.

V

The object of this article has been to provide a much firmer basis than previously existed for the family descent of Jethro Tull the agriculturist and to resolve some of the chronological problems in his biography. What strikes an outside observer is the degree to which Tull's invention was mothered by necessity. His pioneer work seems to have developed pragmatically in response to a series of financial setbacks which had begun by undermining the basis of the social standing for which he had been educated. A victim of the economic forces of his day, the pressure of those forces gave a naturally ingenious mind the driving urge to experiment and to innovate. This response enabled him to maintain a precarious link with genteel society, whose intelligentsia (eg, Cathcart) accepted him, despite his impoverishment, as a practical and beneficial innovator.

Historical Context of Jethro Tull's Work

There were also broader pressures at work that drove the need for a new method of agriculture. The agricultural historian Rowland Prothero, a fellow of the All Souls College at Oxford, in his *English Farming, Past and Present* (1917) summarizes a period of agricultural, scientific and cultural upheaval driven by intense market pressure driven by poor governmental policies concerning the rights of landowners and farmers to plant, tend and harvest crops.

The gigantic advance of agriculture in the nineteenth century dwarfs into insignificance any previous rate of progress. Yet the change between 1700 and 1800 was astonishing. England not only produced food for a population that had doubled itself, as well as gram for treble the number of horses, but during the first part of the period became, as M. de Lavergne has said, the granary of Europe. Population before 1760 grew so slowly that the soil, without any great increase in farming skill or in cultivated area, produced a surplus. Under the spur of the bounty, land which had been converted to pasture was again ploughed for corn, and proved by its yield that it had profited by the prolonged rest. The price of wheat, between the years 1713 and 1764, in spite of large exports, averaged 34s. 11 d. per quarter; poor-rates fell below the level of the preceding century ; real wages were higher than they had been since the reign of Henry VI. In England, at least, there was little civil war or tumult, no glut of the labour market, no sudden growth of an artisan class. The standard of living improved. Instead of the salted carcases of half-starved and aged oxen, fresh meat began to be eaten by the peasantry. Wheaten bread ceased to be a luxury of the wealthy, and, at the accession of George III. had become the bread-stuff of half the population.

Politically and morally, the period was corrupt and coarse ; materially, it was one of the Golden Ages of the peasant. The only drawbacks to the general prosperity of agriculture during the first half of the century were the visitations of the rot, and of the cattle plague. Ellis (in his Shepherd's Sure Guide, 1749.) speaks of the rot in 1735 as " the most general one that has happened in the memory of man . . . the dead bodies of rotten sheep were so numerous in roads, lanes, and fields, that their carrion stench and smell proved extremely offensive to the neighbouring parts and the passant travellers." A newer and more mysterious scourge was the cattle plague. Starting in Bohemia, it travelled westward, devastated the north of France, and three times visited England. The only remedy was to slaughter infected animals ; in a single year the Government, paying one-third of the value, expended £135,000 in compensation.

The great changes which English agriculture witnessed as the eighteenth century advanced, and particularly after the accession of George III. (1760), are, broadly speaking, identified with Jethro Tull, Lord Townshend, Bakewell of Dishley, Arthur Young, and Coke of Norfolk. With their names are associated the chief characteristics in the farming progress of the period, which may be summed up in the adoption of improved methods of cultivation, the introduction of new crops, the reduction of stock-breeding to a science, the provision of increased facilities of communication and of transport, and the enterprise and outlay of capitalist landlords and tenant-farmers. The improvements which these pioneers initiated, taught, or exemplified, enabled England to meet the strain of the Napoleonic wars, to bear the burden of additional taxation, and to feed the vast centres of commercial industry which sprang up, as if by magic, at a time when food supplies could not have been provided from another country. Without the substitution of separate occupation for the ancient system of common cultivation, this agricultural progress was impossible. But in carrying' out the necessary changes, rural society was convulsed, and its general conditions revolutionised. The divorce of the peasantry from the soil, and the extinction of commoners, open-field farmers, and eventually of small freeholders, were the heavy price which the nation ultimately paid for the supply of bread and meat to its manufacturing population.

Neither the reclamation of wastes, nor the break-up of openfield farms, nor the appropriation of commons, were novelties. For the last three centuries the three processes, which are generally spoken of as enclosures, had all been proceeding at varying rates of progress. But in the period from 1760 to 1815 each received an immense impetus, partly from the rise in the price of corn, partly from the consequent increase in rental values, partly from the pressure of a growing population, partly from the improved standard of agriculture. The literary struggle in advocacy or condemnation of enclosures still continued. But the advocates were gaining the upper hand. In the first half of the eighteenth century, there are at least two notable contributions to the literature of the subject by champions of enclosures, and only one of any importance by an opponent.

By the new writers, the unprofitable nature of the use of land under common tillage or common pasture is insisted upon. Thus Timothy Nourse, Gent., in his Campania Foelix; or Discourse of the Benefits and Improvements of Husbandry (1700), vigorously attacks commons as "Seminaries of a lazy Thieving sort of People." In his opinion their live-stock were as unprofitable to the community as the commoners themselves. Their sheep are described as "poor, tatter'd, and poyson'd with the Rot," their cattle "as starv'd, Todbellied Runts, neither fit for the Dairy nor the Yoke." So, also, an anonymous author in a short and pithy tract, An Old Almanack (with some considerations for improving commons) printed in 1710. With a Postscript (1734-5), suggests that, if the landowner and twothirds, in number and value, of those interested in an open-field farm and common agreed to an enclosure, their consent should override the opposition of the minority. "Will the Commoners complain," he asks, "for want of their Commonage? This they can't do, for few of them have any Cattle, and whether they have or not, there is Recompence out of the Inclosures will more than treble their Loss? Will the Incumbents complain? What! for converting the dry Commons into Corn, and the Fenns into Hemp and Flax. Witt the Ingrossers of Commons complain, who eat up their own Share and others too? This they dare not. But won't those honest Men complain who now live upon the Thefts of Common? And not with the least Reason, but then there will be Work for them.' But the two important advocates of enclosures were the brothers John and Edward Laurence. In A New System of Agriculture (1726) a note is struck which sounded more loudly as towns grew, as, with their growth, the demand increased for meat, milk, and butter, as agriculture unproved, as communication was facilitated. The author, the Rev. John Laurence, Rector of Bishops Wearmouth, treats open-field farms as obstacles to agricultural progress. He insists on enclosures and separate occupation as the best means of increasing produce and of raising rents. He dwells on the rapid progress which enclosures were then making, points out the great rise in rental value consequent on increased produce, and argues that so far from injuring the poor, enclosures will rather create a

new demand for labour by the introduction of improved tillage and pasturefarming, will give employment in fencing and ditching, and remove the attractions of wastes and open spaces, which 'draw to them the poor and necessitous only for the advantage of pilfering and stealing.' In The Duly of a Steward to his Lord (1727) Edward Laurence, himself a land-surveyor, and apparently agent to the Duke of Buckingham, argues the case from the point of view of better and more economical management. A new skilled profession was growing up. It is prophetic of future changes that Laurence points out the evils of employing "country-Attorneys (not skilled in Husbandry)" in the management of landed property, and argues that the gentry should allow handsome salaries to their stewards, who could, if inadequately paid, adopt other means of enriching themselves. A champion of "engrossing," he insists on the advantages of consolidating small holdings in larger farms. He urges stewards to prevent piecemeal enclosures by individuals, to substitute leaseholds for copyholds, to buy up any freeholds on the estate which lie in intermixed strips, as necessary preliminaries to any successful and general scheme for the enclosure of open-fields and commons. The other side to the picture is vigorously painted by John Cowper in his Essay proving that Inclosing Commons and Common-Field-Lands is Contrary to the Interest of the Nation (1732). He answers the arguments of the two Laurences, arguing that enclosures necessarily injure the small freeholder and the poor, and pleading that, so far from encouraging labour, they depopulate tho villages in which they have been carried out. Speaking of the small freeholder, he says that "none are more industrious, none toil and labour so hard. ... I myself have seen within these 30 years, above 20 Lordships or parishes enclosed, and everyone of them has thereby been in a manner depopulated. If any one can shew me where an Inclosure has been made, and not at least half the inhabitants gone, I will throw up the argument."

In the passages quoted from these five books are outlined some of the principal points in the dispute which was fought out in the next eighty years. On the one side are pleaded the pernicious effects of commons on the inhabitants of the neighbourhood and their live-stock; the absence of any legal title to many of the rights claimed over pasture commons, and their frequent abuse by commoners; the obstacles to farming improvement which were presented by open arable fields; the unprofitable use of land occupied in common; the commercial and productive advantages of enlarged, separate holdings. On the other side is urged the injury which the break-up of open-field farms and the partition of commons inflicted on small owners and occupiers of land. Much was to be said from both points of view. Many sweeping assertions were made, both by advocates and opponents, which were true of one district but untrue of another. Both socially and economically, the reclamation of wastes, the extinction of open-field farms, the appropriation of commons, might be justified by the urgent necessity of developing the productiveness of the soil, and of increasing to the fullest extent the food resources of the country. In favour of the first two changes, most agricultural writers are agreed; in dealing with the commons, it is at least doubtful whether the best possible course was always adopted.

From the productive point of view, the amount of waste land was a standing reproach to agriculture. The disappearance of the wild boar and the wolf in the reign of Charles II. suggests some diminution of the area in which those animals had harboured. But in 1696 Gregory King had estimated the heaths, moors, mountains, and barren lands of England and Wales at ten million acres, or more than a quarter of the total area. In all probability, the estimate is wholly inadequate. But, assuming the calculation to be approximately correct, it affords some measure of comparison with conditions at the close of the eighteenth century. In 1795 the Board of Agriculture (Report of the Committee of the Board of Agriculture (1795)). The total acreages are over-estimated stated that over 22 million acres in Great Britain were uncultivated, of which 7,888,977 acres were in England and Wales. Here too there is probably a gross under-estimate.

Arthur Young, twenty years before (Observations on the Present State of Waste Lands of Great Britain, 1773. Young's calculations arc also based on an exaggerated estimate of the acreage of England and Wales), had called attention to the extent of land lying waste in Great Britain. "There are," he says, "at least 600,000 acres waste in the

single county of Northumberland. In those of Cumberland and Westmoreland, there are as many more. In the north and part of the West Biding of Yorkshire, and the contiguous ones of Lancashire, and in the west part of Durham, are yet greater tracts; you may draw a line from the north point of Derbyshire to the extremity of Northumberland, of 150 miles as the crow flies, which shall be entirely across waste lands : the exception of small cultivated spots very trifling." It was across this district that Jeanie Deans travelled in the days of George II., when great districts of Northumberland were covered with forests of broom, thick and tall enough to hide a Scottish army. Lancashire in 1794 still had 108,500 acres of waste, and Rossendale remained a chace. As late as 1794, three-quarters of Westmoreland, according to Bishop Watson, lay uncultivated. In 1734 the forest of Knaresborough had surrounded Harrogate so thickly that "he was thought a cunning fellow that could readily find out those Spaws." Even in the last decade of the eighteenth century, 265,000 acres of Yorkshire were lying waste, yet largely capable of cultivation. Up to the accession of George III., that part of the East Riding which was called the Carrs, from Bridlington Quay to Spurn Point, and inland as far as Driffield, was an extensive swamp producing little but the ague; willow trees marked out the road from Hull to Beverley, and the bells rang at dusk from the tower of Barton-upon-Humber to guide belated travellers. Great tracts of Derbyshire were "black regions of ling.". From Sleaford to Brigg, "all that the devil o' erlooks from Lincoln Town," was a desolate waste, over which wayfarers were directed by the land lighthouse of Dunstan pillar. No fences were to be seen for miles— only the furze-capped sand-banks which enclosed the warrens. The high ground from Spilsby to Caistor was similarly a bleak unproductive heath. Robin Hood and Little John might still have sheltered in Sherwood Forest, which occupied a great part of Nottinghamshire. The fen districts of the counties of Cambridge, Huntingdon, Lincoln, and Northampton continued to defy the assaults of drainage. Even in the neighbourhood of London similar conditions prevailed. Nathaniel Kent, writing in 1775 (Hints to Gentlemen of Landed Property), says "that within thirty miles of the capital, there is not less than 200,000 acres of waste land." As late as 1793, Hounslow Heath and Finchley Common were described as wastes, fitted only for "Cherokees and savages." In 1791, the Weald of Surrey still bore evidence of its desolation in the posts which stood across it as "guides to letter-carriers." In Essex, Epping and Hainault Forests were in 1794 "known to be a resort of the most idle and profligate of men ; here the undergraduates in iniquity commence their career with deer stealing, and here the more finished and hardened robber retires from justice." Counties more remote from London had a still larger area of wastes. When Young made his Farmer's Tours in the first decade of the reign of George III., Sedgmoor was still one vast fen, the Mendip Hills were uncultivated, and eighteen thousand acres on the Quantock Hills lay desolate. Over Devonshire, Cornwall, and the whole of Wales, stretched, in 1773, "immense" tracts of wastes. To bring some of these wastes into cultivation was part of the work which agriculturists undertook in the eighteenth century, and if the estimates of Gregory King (1696) and of the Board of Agriculture (1793) are approximately correct, upwards of two million acres were added to the cultivated area before the close of the period.

It is possible that in 1700 at least half the arable land of the country was still cultivated on the open-field system—that is, in farms by associations of agricultural partners who occupied intermixed strips, and cultivated the whole area under common rules of cropping. Out of 8,500 parishes, which in round numbers existed at the Reformation, 4,500 seem to have been still laid out, in whole or in part, on this ancient method. John Laurence in 1726 had calculated that a third of the cultivated area "is what we call Common Fields." The agricultural defects of the openfield system were obvious and numerous. So long as farming had been unprogressive, and population had remained stationary, the economic loss was comparatively unimportant. When improved methods and increased resources were commanded by farmers, and hen the demand for food threatened to outstrip the supply, the nded for change became imperative. Under the primitive system, the area under the plough was excessive, and much land, which might have been more profitably employed as pasture, was tilled for corn. A quantity of the arable land was wasted in innumerable balks and footpaths. All the occupiers were bound by rigid customary rules, compelled to treat all kinds of soil alike, obliged to keep exact

time with one another in sowing and reaping their crops. Freeholders on open-field farms were only half-owners. No winter crops could be grown so long as the arable fields were subjected to common rights of pasture from August to February. It meant financial ruin, if any member of the community grew turnips, clover, or artificial grasses for the benefit of his neighbours. The strips of land occupied by each partner were too narrow to admit of crossploughing or cross-harrowing, and on heavy land this was a serious drawback. Drainage was practically impossible, for, if one man drained or water-furrowed his land, or scoured his courses, his neighbour might block his outfalls. It was to carry off the water that the arable land was heaped up into high ridges between two furrows. But the remedy was almost as bad as the disease. The richness of the soil was washed off the summit of the ridge into the trenches, which often, as Kentl records, contained water three yards wide, dammed back at either end by the high-ridged headlands. The cultivated fields were generally foul, if not from the fault of the occupier, from the slovenliness of his neighbours ; the turf-balks harboured twitch ; the triennial fallows left their heritage of crops of docks and thistles. The unsheltered, hedgeless openfields were often hurtful to live-stock, though the absence of hedges was not without its advantages to the corn. The farm-buildings were gathered together in the village, often a mile or more from the land. As each man's strips lay scattered over each of the openfields, he wasted his day in visiting the different parcels of his holding, and his expenses of manuring, reaping, carting, and horsekeeping were enormously increased by the remoteness of the different parts of his occupation. Vexatious rights interfered with proper cultivation. One man might have the right to turn his plough on another's strip, and the victim must either wait his neighbour's pleasure or risk the damage to his sown crops. "Travellers," as Joseph Lee remarked in 1656, "know no highwaies in the common fields," each avoided his predecessor's ruts, and cattle trespassed as they passed. For twenty yards on either side of the track the growing corn was often spoiled. The sheep were driven to the commons by day, and in the summer folded at night on the fallows. Otherwise the manure of the live-stock was wasted over the wide area, which the animals traversed to find their scanty food. Unable to provide winter keep, and fettered by the common rights of pasture which each of the partners enjoyed over the whole of the arable land, farmers reared lambs and calves under every disadvantage. During the summer months, when the horses and cattle were tethered on the unsheltered balks, they lost flesh and pined in the heat. Ill-fed all the year round, and half-starved in the winter, the live-stock dwindled in size. The promiscuous herding of sheep and cattle generated every sort of disorder. The common pasture was pimpled with mole-heaps and ant-hills, and, from want of drainage, pitted with wet patches where nothing grew but rushes. The scab was rarely absent from the crowded common-fold, or the rot from the ill-drained plough-land and pasture. No individual owner could attempt to improve his flock or his herd, when all the cattle and sheep of the village grazed together on the same commons. (Hints to Gentlemen of Landed Property, by Nathaniel Kent, 1775. Vindication of a Regulated Enclosure, p. 24)

The open-field system was proverbially the source of quarrels. Litigation was incessant. It was easy for men to plough up a portion of the common balks or headlands, to shift their neighbour's landmarks, or poach their land, by a turn of the plough, or filch their crops when reaping. Robert Mannyng in his Handlyng Synne (1303) had condemned the "fals husbandys" that "ere aweye falsly mennys landys," and William Langland in Piers Plowman (1369) had denounced the ploughman who "pynched on" the adjoining half-acre, and the reapers who reaped their neighbour's ground. Tusser repeats the complaint of the mediaeval moralists against the 'champion' or open-field farmer...

...Gascoigne in The Steel Glasse (1576) condemns the open-field farmer who "...set debate between their lords by earing up the balks that part their bounds." Joseph Lee repeats the charge. "It is," he says, "a practice too common in the common fields, where men make nothing to pull up their neighbour's landmark, to plow up their land and mow their grasse that lyeth next to them." For open-field farmers the curse in the Commination Service had a real meaning. Edward Laurence 1 (Duty of a Steward to his Lord, 1727) dwells on the temptations to dishonesty which the unfenced lands and precarious boundaries of open-fields offered to the needy, and the same point is repeatedly insisted upon by

the Reporters to the Board of Agriculture at the end of the eighteenth century. Hence it was that open-field farmers agreed among themselves as little as "wasp doth with bee." Hence also came the numerous law-suits. "How many brawling contentions," says Lee, "are brought before the Judges every Assizes by the inhabitants of the common fields."

Speaking generally, enclosure meant the simultaneous processes of consolidating the intermixed strips of open-field farms and of dividing the commons attached to them as adjuncts of the arable holdings. But this was not universally the case. Sometimes the arable farm had been enclosed, and only the pasture common remained to be divided. Sometimes the reverse was the case; the common had gone, and only the arable land remained to be enclosed. Sometimes land, previously enclosed by agreement or piecemeal by individuals, was re-enclosed under a general scheme, probably for purposes of redistribution. Sometimes the acreage mentioned in Inclosure Acts, as tested by the awards, is exaggerated, more rarely under-estimated. All these differences make accurate calculations of the actual area affected by the appropriation of pasture-commons and the extinction of open-field farms extremely difficult, if not impossible. Now that the commons as adjuncts of arable farming have greatly contracted in area, their comparative disappearance is deplored on both economic and social grounds, in accordance with ideas which are of recent growth. It might have been possible to regulate their use to greater profit, or to preserve them as open spaces for recreation and as the lungs of large towns, or to divide them on methods which recognised more fully the minor rights claimed by small commoners, and would thus have benefited a larger section of the community. But so long as the herbage of the commons, both in legal theory and historical origin, formed an essential part of the arable farm, and was subject to rights claimed against all the world by the privileged occupiers of the tillage land, there were practical difficulties in the way of each of these possible courses. Agriculturists scarcely looked to those of England, and their methods of raising crops had remained unchanged since the Battle of Bannockburn. Advocates of enclosure in England might legitimately argue that the rapid progress of Scottish farming dates from the General Enclosure Act for Scotland which was passed in 1695.

The south-eastern counties were the first to be improved. Forty years before (1661), John Ray (Select Remains of John Ray, London, 1760) had painted an unfavourable picture of the condition of the inhabitants. "The men seem to be very lazy, and may be frequently observed to plow in their cloaks. . . . They have neither good bread, cheese, or drink. They cannot make them, nor will they learn. Their butter is very indifferent, and one would wonder how they could contrive to make it so bad. They use much pottage made of coal-wort, which they call kecd, sometimes broth of decorticated barley. The ordinary country houses are pitiful cots, built of stone, and covered with turves, having in them but one room, many of them no chimneys, the windows very small holes, and not glazed." Alexander Garden of Troup describes the farming system which was followed in 1686. The land was divided into in-field and out-field. The in-field was kept "constantly under corne and bear, the husbandmen dunging it every time years, and, for his pains, if he reap the fourth corne, he is satisfied." The out-field was allowed to grow green with weeds and thistles, and, after four or five years of this repose, was twice ploughed and sown with corn.

Three crops were taken in succession ; then, when the soil was too exhausted to repay seed and labour, it reverted to its weeds and thistles. Sir Archibald Grant (Miscellany of the Spalding Club, Aberdeen, 1841-2, vol. ii. p. 96 etc.) of Monymusk in Aberdeenshire, says that in 1716 turnips grown in fields by the Earl of Rothes and a few others were objects of wonder to the neighbourhood, that, except in East Lothian, no wheat was grown, that on his own estate there were no enclosures, no metalled roads, and no wheel-carriages. On the family property, when his father allowed him to undertake the management— "there was not one acre inclosed, nor any timber upon it, but a few elm, oycamore, and ash about a small kitchen garden adjoining to the house, and some stragling trees at some of the farm-yards, with a small copswood, not inclosed, and dwarfish, and broused by sheep and cattle. All the farmes ill disposed, and mixed ; different persons having alternate ridges ; not one wheel-carriage on the esteat, nor indeed any one road that would alow it. ... The whole land raised and uneven, and full of stones, many of them very large, of a hard iron quality, and all

the ridges crooked in shape of an S, and very high and full of noxious weeds, and poor, being worn out by culture, without proper manure or tillage. . . . The people poor, ignorant, and slothfull, and ingrained enimies to planting, enclosing, or any improvements or cleanness."

Neither in Scotland nor in England were open-field farmers, or tenants-at-will, or even leaseholders for lives, likely to initiate changes in the cultivation of the soil. It was almost equally idle to expect that small freeholders would attempt experiments on the agricultural methods of their forefathers, which, in a single season, might bring them to the verge of ruin. In both countries, it was the large landlords who took the lead in the agricultural revolution of the eighteenth century, and the larger farmers who were the first to adopt improvements. Both classes found that land was the most profitable investment for their capital. Their personal motives were probably, in the main, self-interested, and a rise in rental value or in the profits of their business was their reward. But though philanthropy and farming make a fractious mixture, the movement was of national value. When the sudden development of manufacturing industries created new markets for foodsupplies, necessity demanded the conversion of the primitive selfsufficing village-farms into factories of bread and meat. For more than half a century the natural conservatism or caution of agriculturists resisted any extensive change. Down to 1760 the pressure of a growing population was scarcely felt. Nor were the commercial advantages of scientific husbandry so clearly established, even in 1790, as to convince the bulk of English landlords of the wisdom of adopting improved methods.

The comparatively slow progress of the movement is illustrated by the variations in the number of Enclosure Acts passed before and after 1760. But it must always be remembered that an Act of Parliament was not the only method of enclosure, and that counties had been enclosed, either entirely or mainly, without their intervention. In Tudor times open-field arable lands and common pastures had been sometimes enclosed not only by agreement or purchase, but by force or fraud. Sometimes they had been extinguished, in whole or in part, by one individual freeholder, who had bought up the strips of his partners. Sometimes, where northern counties of Cheshire, Lancashire, Westmoreland, Cumberland, Northumberland, and Durham. No generalisation will explain why these districts should have been enclosed sooner or more easily than elsewhere.1 The facts remain that no Parliamentary enclosures took place in Kent, Devonshire, Cornwall, or Lancashire; that as early as the middle of the sixteenth century Kent, Essex, and Devonshire were stated by a Tudor writer to be the most enclosed and wealthiest counties;2 that in 1602 Carew, the historian of Cornwall, recorded that his countrymen 'fal everywhere from Commons to Inclosure, and partake not of some Eastern Tenants envious dispositions, who will sooner prejudice their owne present thrift, by continuing this mingle-mangle, than advance the Lords expectant benefit, after their terme expired"; that in 1656 Joseph Lee mentions Essex, Hereford, Devonshire, Shropshire, Worcester as ' wholly enclosed" ; that in 1727 the Rev. John Laurence says that "as to the Bishoprick of Durham, which is by much the richest Part of the North, Nine Parts in Ten are already inclosed." The question may be stated in figures, which are collected from Dr. Slater's The English Peasantry and the Enclosure of Common Fields (1907), Appendix B.

Since the last half of the fifteenth century the enclosing movement had been continuously in operation. Why, in the eighteenth and nineteenth centuries, was more land enclosed by Act of Parliament in some districts than in others?...

...The answer depends on local circumstances or agricultural conditions. Disturbances on the northern and western borders were unfavourable to settled agriculture, and village farms and commons never throve extensively in the counties adjoining the borders of Scotland and Wales. In districts which abounded in fens, marshes, moorlands or hills, the space occupied by open-fields was necessarily limited, although the inhabitants of the neighbourhood may have exercised over these waste tracts rights of goose-pasture, of cutting fuel, turf, or reeds, or, where possible, of grazing. But the land, when enclosed, was taken in from the wild, and was, from the first, cultivated in separate holdings. Other districts, which naturally were clothed with extensive woodlands or forest, were enclosed piecemeal by individual

enterprise for individual occupation. After the end of the fourteenth century, it is unlikely that any cleared land would have been cultivated in common. Other districts, lastly, which were industrially developed by the neighbourhood of large towns, or by the existence of some manufacturing industry, were early enclosed, either because of the demand for animal food and dairy produce, or because of the scarcity of purely agricultural labour.

On these general principles, before the era of Parliamentary enclosure, may be partially explained the comparative absence or disappearance of open-fields and pasture commons in the border counties, in the Wealds of Surrey, Kent, Sussex, in the forest districts of Hampshire, Essex, Warwickshire, or Nottinghamshire, in the neighbourhood of London or Bristol, or in the clothing districts of Devon and Somerset, of Essex, and Suffolk, or of parts of Norfolk. No doubt enclosure of cultivated land by agreement was at this period chiefly made for grazing and dairying purposes. But at the same time a large addition was being continuously made to the arable area of the country, partly by the reconversion of grass-land to tillage after fertility had been restored by rest, partly by the reclamation and enclosure of new land well adapted for grain. "Consider," writes Blith, "the Wood-lands who before Enclosure were wont to be releeved by the Fieldon with Corn of all sorts, And now are grown as gallant Corn Countries as be in England." (English Improver, chap. xix.) This addition to tillage necessarily affected the whole of the old corn-growing districts, where a large acreage, more fitted for pasture than for tillage, was kept under the plough by the open-field system. The eSect was more and more felt when in creating facilities of communication enabled farmers to put their land to the best use by relieving them from the old uniform necessity of growing corn for the locality.

Elsewhere, the early or late enclosure of land was in the main determined by such agricultural reasons as climate or soil. Enclosure took place first, where it paid best agriculturally. In the moister climate of the South-west and West the rigid separation of arable from pasture was unnecessary. In some parts of the country the suitability of the land for hops or fruit necessitated early enclosure. Blith's reference to the plantation of the hedgerows with fruit-trees in "Worcestershire, Hereford, and Glostershire and great part of the county of Kent" points to separate occupation in the first half of the seventeenth century. In other parts, if corn-land was more adapted to pasture, it was, under the new conditions, enclosed and laid down to grass. It was thus that the grazing districts on the water-bearing pasture belt of the Midlands, or the dairying districts of Gloucestershire or Wiltshire came into separate occupation. So also, where the soil was of a quality to respond quickly to turnips, clover, and artificial grasses, it was enclosed in order that it might profit by the new discoveries. This was the case on the light soils of Norfolk, where, as Houghton noted, turnip husbandry had been introduced with success before the close of the seventeenth century. This early use of roots is confirmed by Defoe, who says of Norfolk; "This part of England is remarkable for being the first where the Feeding and Fattening of Cattle, both Sheep as well as black Cattle, with Turnips, was first practis'd in England" (A Tour thro' the whole Island of Great Britain (2nd edition, 1738), vol. i. i. 60-61. Defoe began his tour in 1722).

Where land did not appear to be so immediately susceptible to the influence of these improvements, which were still imperfectly understood, the question of enclosure, and of the use to which the land was put, became mainly one of expense. Only the best and strongest land was able to endure the open-field system without exhaustion. To separate occupiers, eighteenth century improvements offered new means of restoring the fertility of exhausted soil. At the same time the revolution in stock-breeding held out new temptations to graziers. Much worn-out arable land of indifferent or medium quality was enclosed because its produce was declining...

...Up to the accession of George III (1760) prices of corn ruled low. More than once in the preceding period (1700-60) loud complaints were heard of agricultural depression, of farmers unable to pay their rents, of the small gentry forced to sell their estates, of landlords compelled by loss of income to curtail their establishments. As yet there was no scarcity caused by population outstripping production, no increased demand for food supplies from great industrial centres. But without these spurs to farming progress, preparations for advance were being made, and far-

reaching improvements in the cultivation of arable land had been already tested or initiated by men like Jethro Tull and Lord Townshend.

In the progress of scientific farming Tull—is one of the most remarkable of pioneers. His method of drilling wheat and roots in rows was not generally adopted till many years after his death. But the main principles which he laid down in his Harse-Hoeing Husbandry (1733) proved to be the principles on which was based an agricultural revolution in tillage. The "greatest individual improver" that British agriculture had ever known, he sought to discover scientific reasons for observed results of particular practices. He was thus led to strike out for himself new and independent lines of investigation.

The chemistry of plant-life was in its infancy, the science of vegetable physiology an almost untrodden field of knowledge. Into these comparatively unexplored regions Tull advanced alone, and, by minute observation of nature and stubborn tenacity of purpose, he advanced far. Considering his difficulties and disadvantages, it is a remarkable proof of his real genius that he should have discovered so much. He lived in a solitary farmhouse, remote from such scientific aid as the age afforded, or from friends in whom he could confide. His microscope was "very ordinary;" his appliances were self-made; his experiments thought out for himself. He made his observations and notes, tortured by the "stone, and other diseases as incurable and almost as cruel." His labourers, by whom he was, metaphorically, "insulted, assaulted, kicked, cuffed and bridewelled," tried his patience beyond endurance.

His son turned out an extravagant spendthrift who ended his days in the Fleet Prison. Ill-health and misfortune made him irritable. His sensitive nature was galled alike by the venomous criticism of the book (The new Horse-Houghing Husbandry, 1731. (Five chapters of the subsequent book which were pirated and re-printed in Ireland as the New Horse Hoing Husbandry, 1733. Supplement, 1740. William Cobbett edited and published the Horse-Hoeing Husbandry in 1822 : 2nd edition, 1829.) in which he published the results of his thirty years' experience as a farmer, and by its shameless plagiarism. Yet he never lost his confidence that his "practice would one day become the general husbandry of England."

The son of a Berkshire landowner, Jethro Tull was born at Basildon in 1674. From Oxford, which he left without taking a degree, he entered Gray's Inn as a law student, made the grand tour of Europe, and was called to the Bar in 1699. Scholar, musician, traveller, lawyer, he became a farmer not by choice but from necessity. In 1699 he settled down with his newly married wife at "Howbery" Farm (It is remarkable that this farm now (1912) contains one of the most highly cultivated pieces of land in the world) in the parish of Crowmarsh, near Wallingford. There he lived ten years. In 1709 he moved to Mount Prosperous, a hill-farm in the parish of Shalbourn, on the borders of Berkshire and Wiltshire. Two years later, the failure of his health drove him abroad to save his life. Returning in 1714 to Mount Prosperous, he remained there till his death in 1740, living in a house, covered with home-made glazed tiles, which Arthur Young, who visited the place fifty years later, described as a "wretched hovel." At Crowmarsh Tull invented his drill. As a gentleman-farmer he found himself at the mercy of his farm-servants. From his own experience he verified the truth of the saying : "He who by the plough would thrive / Must either hold himself or drive."

He determined to plant his whole farm with sainfoin. But "seed was scarce, dear and bad, and enough could scarce be got to sow, as was usual, seven bushels to the acre." He set himself to conquer the difficulty. By constant observation and experiment he learned the difference between good and bad seed, as well as the advantages of care in selection, of cleaning, steeping, and change ; he also proved that a thin sowing produced the thickest crop, and discovered the exact depth at which the seed throve best. "So," he says, "I caused channels to be made, and sowed a very small proportion of seed, covered exactly. This was a great success." But it was also an innovation, and his labourers struck in a body. Tull refused to be beaten. He set his inventive faculty to work "to contrive an engine to plant sainfoin more faithfully than hands would do." His knowledge of the mechanism of an organ stood him in good stead. The groove,

tongue, and spring of the sounding board suggested the idea of an implement which delivered the seed through notched barrels. Behind was attached a bush harrow which covered the seed. The machine answered its purpose, and he afterwards introduced several improvements of his original plan.

The originality of his invention cannot justly be disputed, though his enemies, and he had many, asserted that he brought the machine from abroad or had been preceded by Plat, Plattes or Worlidge. All four inventors saw the advantage of sowing not broadcast but in rows. Both Plat and Plattes were setters, rather than drillers, of corn, and they took for their model the dibbing of beans or peas. Plat seems to have invented a board, to which were fixed iron dibbers. Something of this sort is depicted on the title-page of Edward Maxey's New Instructionl (1601). Gabriel Plattes designed a machine to punch holes in the land as it went along. But, as is pointed out in Hartlib's Legacie, the author of which suggested hoeing the furrows by hand, the machine would have been practically useless in wet and heavy land. Neither Plat nor Plattes contemplated a mechanical sowing ; both intended the seed to be deposited by hand. In this respect Worlidge's drill was an advance on his predecessors. He placed coulters in front of the seed-boxes, from which the seed was deposited through barrels into furrows. But he never made or tried his implement. When Professor Bradley in 1727 constructed a machine from Worlidge's drawing, he found that it would not work. To Tull, therefore, belongs the credit of the first drill which served any practical purpose.

Tull's many mechanical inventions were less valuable than the reasons which he gave for their employment. His implements were speedily superseded; his principles of agriculture remain. During his foreign travels he was impressed with the cultivation of vineyards in the south of France, where frequent ploughings between parallel rows of vines not only cleaned the land, but worked and stirred the food-beds of the plants until the vintage approached maturity. Tull determined to extend the principles of vine-culture to the crops of the English farm. He argued that tillage was equally necessary before and after sowing. When crops were sown, nature at once began to undo the effect of previous ploughings and sowings. The earth united, coalesced, consolidated, and so shut out the air and water from the roots, and decreased the food supply at the moment when the growing plants most needed increased nourishment. To some extent the use of farm yard manure kept the land friable; but it also stimulated the growth of weeds. The better course, therefore, was to keep the land pulverised by tillage and so to prevent the contraction of the food area of the growing crops. So long as wheat and turnips were sown broadcast, this method could not be satisfactorily employed. But if they were drilled in rows, divided by sufficiently wide intervals, the principles of vine culture could be profitably applied.

In two ways the crops benefited by constant tillage. In the first place, the land was kept clean from weeds, and so saved from exhaustion. In the second place, the repeated pulverisation of the soil admitted air, rain-water, and dews to the roots of the plants, and extended the range from which their lateral growths drew their food supplies. In some respects lull's system failed. His rows of thinly sown wheat, for instance, were drilled so far apart that the plants were slow to mature, and therefore, if sown late in the year, were more susceptible to blight. But for turnips his method was admirable. Incidentally also he found that his "drill husbandry" was a substitute not only for fallows, but for farmyard dung, which he dreaded as a weed-carrier. Without fallows or manure, he grew on the same land, by constant tillage, for thirteen years in succession heavier wheat crops, from one-third of the quantity of seed, than his neighbours could produce by following the accepted routine. By this discovery he anticipated one of the most startling results of the Rothamsted experiments.

The chief legacies which Jethro Tull left to his successors were clean farming, economy in seedings, drilling, and the maxim that the more the irons are among the roots the better for the crop. It was along these lines that agriculture advanced. On openfield farmers who sowed their seed broadcast, thickly, and at varying depths, Tull's experiments were lost. Equally fruitless, so far as his immediate neighbours were concerned, was his demonstration of the value of

sainfoin and turnips, or the drilling of wheat and roots. Even his system of drilling roots was neglected in England, till it had been tested and adopted in Scotland.

It was not till Tull's principles were put in practice by large landlords in various parts of the country that their full advantages became apparent. In England this was the work of men like Lord Townshend at Raynham in Norfolk, Lord Ducie at Woodchester in Gloucestershire, or Lord Halifax at Abbs Court near Waltonon-Thames. In Scotland the "Tullian system" was enthusiastically preached by the Society of Improvers in the Knowledge of Agriculture in Scotland (founded 1723, dissolved 1745), by Lord Cathcart, and by Mr. Hope of Rankeillor. In the Heart of Midlothian, Scott is true to the spirit, if not to the details, of history when he credits the Duke of Argyll with a keen interest in all branches of farming and the introduction into Inverness-shire of a herd of Devonshire cattle. Agriculture had for the moment become, a fashion in society, a part, perhaps, of the artificial movement which in gardening created the Landscape School. Tull's system was discussed at Court. It was explained to George II., and therefore interested Lady Suffolk. The practical Queen Caroline subscribed to the publication of the Horse-Hoeing Husbandry.

Pope loved to "play the philosopher among cabbages and turnips." Sir Robert Walpole, it is said, opened the letters of his farm steward before he broke the seals of correspondence on State affairs; Bolingbroke caused Dawley Farm to be painted with trophies of ricks, spades, and prongs, and, propped between two haycocks, read Swift's letters, uplifting his eyes to heaven, not in admiration of the author but in fear of rain. "Dawley," said his political opponents, "has long been famous for a Great Cry and little Wool. Tup Harry become Mutton master." (The Hyp Doctor, No. 32, July 20, 1731.)

Other landowners threw themselves energetically into the practical work of agricultural improvement. Charles, second Viscount Townshend, may be taken as a type of the reforming landlords who took the lead in farming their estates. Born in 1674, he died in 1738, having succeeded to the title and estates of his father when a child of thirteen years old. In his early life, he had played a prominent part in the political history of the country at a critical period. Lord Privy Seal under William III., he served as a Commissioner to treat for the Union of England and Scotland, and, as a joint plenipotentiary with Marlborough, signed the Peace of Gertruydenberg in 1709. In the same year, as Ambassador at the Hague, he negotiated the famous Barrier Treaty. Under George I. and George II., he acted as Secretary of State, was appointed Lord Lieutenant of Ireland, and, as joint Secretary of State with Walpole, directed the foreign policy of Great Britain.

In 1730 Lord Townshend retired from political life to Raynham in Norfolk. There he devoted himself to the care of his estates, experimenting in the farming practices which he had observed abroad, and devoting himself, above all, to improvements in the rotation of crops, and to the field cultivation of turnips and clover, which, in the preceding half century, had been successfully introduced in the county. His land mainly consisted of rush-grown marshes, or sandy wastes where a few sheep starved and "two rabbits struggled for every blade of grass." The brief but exhaustive list of its productions is "nettles and warrens." Townshend revived the ancient but almost obsolete practice of marling the light lands of Norfolk. Farmers believed that marl was "good for the father, bad for the son," till he proved its value on the sandy soil of the county. The tide of fashion set once more in its favour, and farmers found another proverbial saying for their purpose:

"He who marls sand / May buy the land; / He that marls moss / Suffers no loss; / He that marls clay / Throws all away."

By the use of marl alone Young calculates that "four hundred thousand acres have been turned into gardens." Following the lines of Jethro Tull, Townshend drilled and horse-hoed his turnips instead of sowing them broadcast. He was also the initiator of the so-called Norfolk, or four-course, system of cropping, in which cereals, roots, and artificial grasses were alternated.

The introduction of roots and grasses encouraged the farmer to observe the useful rule of never taking two corn crops in succession, saved him from the necessity of leaving a portion of land every year in unproductive fallow, enabled him to carry more stock and maintain it without falling off during the winter months. For the light sands of Norfolk turnips possessed a special value. Boots, fed on the ground by sheep, fertilised and consolidated the poorest soil. Another portion of the crop, drawn off and stored for winter keep, helped the farmer to keep more stock, to obtain more manure, to enrich the land, to increase its yield, to verify the truth of the proverb "A full bullock-yard and a full fold make a full granary." Farming in a circle, unlike arguing, proved a productive process.

So zealous was Townshend's advocacy of turnips as the pivot of agricultural improvement, that he gained the nickname of "Turnip" Townshend, and supplied Pope with an example for his Horatian Illustrations, (15k. ii. Epist. ii. 11. 270-9) ; "Why, of two brothers, rich and restleaa one Ploughs, burns, manures, and toils from sun to sun ; The other slights, for women, sports, and wines, All Townshend's turnips and all Qrosvenor's mines, Is known alone to that Directing Power Who forms the genius in the natal hour."

Townshend's efforts to improve his estates were richly rewarded. On the sandy soil of his own county, his methods were peculiarly successful. Furze-capped warrens were in a few years converted into tracts of well-cultivated productive land. Those who followed his example realised fortunes. In thirty years one farm rose in rental value from £180 to £800 ; another, rented by a warrener at £18 a year, was let to a farmer at an annual rent of £240 ; a farmer named Mallett is said to have made enough off a holding of 1500 acres to buy an estate of the annual value of £1800. Some farmers were reported to be worth ten thousand pounds. But the example only spread into other counties by slow degrees. Outside Norfolk, both landlords and farmers still classed turnips with rats as Hanoverian innovations, and refused their assistance with Jacobite indignation. Even in Townshend's own county, it was not till the close of the century that the practice was at all universally adopted ; still later was it before the improved methods were accepted which converted Lincolnshire from a rabbit-warren or a swamp into cornfields and pasture.

The never-finished book

Jethro Tull called his own work unfinished. In his supplement of 1750, he says that he had to rush his work to the printer for fear that his failing health would not offer him a possibility of waiting to complete it AND see it through the complicated work of scribes, printers, drawers, engravers and the printing process. Thus, he had to print it first and supplement it later – though he understood that even with supplementation, the three parts he provided were imperfect and required further work.

The near-death of the Horse Hoeing Husbandry

Many works (including the Horse Hoeing Husbandry) are either lost or nearly lost to the modern reader—either by too little effort made for their preservation, or by too great of an effort: some books that are fortunate enough to survive the test of time reside in archived special collections (public and private) where they are inaccessible to the majority of readers (either by policies of viewing hours or by the geographical location for the would-be viewer of the collection). And when, by technology, a book is preserved and made available, the would-be reader is still sometimes thwarted: even at the excellent public collegiate library where the majority of the research for this book was conducted, the editors more than one time faced the convenience of microfilm reproductions foiled by the disrepair and unreliability of the machines that would have

read the tape...and, if the machines did work and the film was available, the editors found that the microfilm had not fully preserved the book (smudges, blank or erased places and debris on the film prevented the reading of the words)![29]

And—even when the document is preserved and is accessible—sometimes it is written in a language lost to all but the most learned of linguists: more than once when the editors managed to find and use a copy of an ancient book, they found it to be unintelligible. This language barrier was a costly (but sometimes possible) obstacle to overcome for the editors, yet it would be impossible for the casual reader to learn from such works of worth.

The purpose of this edition is not to diffuse knowledge that is now antiquated or improved, and this edition was not published for the glory of Tull. This edition is for those readers who, like the editors of this edition, do not tire in the endless process and progress of civilization. Indeed, it was Tull's purpose that the reader might learn the scientific theory necessary to improve upon his great contributions to agriculture. It was Tull's wish that, by reading his words, posterity might be empowered to learn to dig deeper.

This book was undertaken in dedication to the same posterity and is intended to preserve and improve its educational merit. It is a supreme act of gentleness to set down not only the learning which has been previously obtained, but to simultaneously train the student on how to gain further knowledge.

A History of the 5th Edition

There have been four previous editions since the first went to press in 1731. The second, published in 1743 for A. Millar, contained various corrections and notes by Tull. Tull died in 1741, but not before he had endorsed the pirating of his work (so that it would be more widely diffused). Few of the unauthorized but forgiven copies remain. In the second printing, minor corrections were made and two sections of "errata" were included. A. Millar's printing provided the basis for all subsequent editions—including the present one. The editors regret that there is little information to be found about A. Millar.

In 1750, Tull's work was discovered (probably in the form of the 1743 reprinting of the second edition) by the efforts of the French agricultural scientist M. Duhamel du Monceau (M. du Monceau, an expert in forestry, fishery, crop and animal systems, was on business from his King to improve the French agricultural industry by the importation and diffusion of agricultural knowledge from foreign countries). M. du Monceau had Tull's work translated into French (by a translator who did not know much of the English agricultural terminology) and edited this French translation in the effort to facilitate the diffusion of the work to other French agricultural scientists. Needless to say, this French translation of the second edition was a poor one, but (it must be said) despite its failures in translation, it was a highly successful edition and one whose ease of reading remains a joy to even modern readers[30]. From the poorly translated French came German, Spanish and even

[29] With such excuse, the editors beg the forgiveness of the reader for the condition of the original documents presented in addendum.

[30] The reader of this edition continues to enjoy M. Monceau's work. Special thanks are due to Mary Choate, who translated the work's introduction into English. For those who can read the original French, the French has been included in its original wording side-by-side with the translation.

Scandinavian editions; Tull and his mechanized, scientific methods became widely known throughout the world...and re-imported to his native land, where he had fallen into relative obscurity.

In 1751, inspired by the interest of the important French agriculturalist, "the third edition, very carefully corrected" (as the title page incorrectly describes) of the *Horse Hoeing Husbandry* was again printed for A. Millar. Motivated by the success of Monceau, this is better than a retranslation of the French into English, but not much better: sometimes Tull's footnotes are inserted into the text, sometimes they remain footnotes; sometimes Tull's text is made into footnotes. It is very mysterious how the editors decided whether to include text as a footnote or as text, but one gains the idea that it was to improve the flow of the work. Not all the original chapters are included and much of the language is altered (for the sake of simplification and clarification, that noble intent of Monceau) to produce a manuscript that is quite "carefully corrected."

Mr. William Cobbett produced a fourth edition of the work in 1821. This fourth edition had a second printing in 1829 with few revisions: English is modernized, some ancient terminology updated and chapters on plows and equipment removed. Cobbett makes minimal efforts towards clarification, attempting to improve Tull's language in places where it is confusing (proper English in Tull's time was quite different than proper English in Cobbett's time). Occasionally, in doing so, he adds in his own language, which is difficult to discern from Tull's; in doing so, he adds in his own thoughts and beliefs, indiscernable from Tull's.

This fifth edition improves on the 1743 reprint of the second edition, leans heavily on Cobbett's modernization and largely ignores the revisions of the other editions. The first edition and the second edition are attached to this Fifth Edition in Volume I and 2 for the curiosity of the reader and to empower the reader to check the editors of this—and future—editions against what was Tull's original work.

The 1743 reprint literally disintegrated while we worked from it's microfilm copy we were at last able to obtain. In fairness, we offered a copy of our copy to the librarians now bereaved of their own, but they declined. Incredibly, the copy made from this microfilm was nearly lost in the systematic attack on a farm we were working on and the home we were living in (and fields, animals and homes those of neighboring farms) by organized criminals residing nearby. Though the story of the farm's destruction is entertaining, including frights and fights for our very lives, it does not belong to this volume; it is only related here because it is an interesting facet to the history and near-destruction of the work, and adds (perhaps?) as much color to the story of the work as Mr. Hidden's *Jethro Tull I, II and III* or the biographies of Monceau and Cobbett.

It is also mentioned as segue so we might say that all that time, we trusted that Tull's work, being the result of science, was in no real danger. Had the Deep Hoeing Husbandry been lost and the knowledge forgot, it is likely that it would be rediscovered at some point in the future.

About the time of the second edition, a *Supplement to the Essay on Horse Hoeing Husbandry containing additions both in Theory and Practice wherein all the objections against that husbandry which have come to the author's knowledge are considered and answered* was published. This is inserted by Cobbett throughout the work as he saw appropriate, both in the body of the work and in the form of margin notes.

It was by mutual agreement of Mary Choate and Aaron Brachfeld that the translation was placed along the original: this the only adequate check against mistranslation, and the comparison is informative if the reader is curious see the slight differences in terminology for the same concepts. More discussion precedes M. du Monceau's preface in the form of a special introduction.

In this we have disagreed with Cobbett: these notes have been added at the end of chapters as endnotes as their character is generally one of summary and commentary, either illuminating supplementary concepts that come into play when the body of the chapter is understood wholly, or commenting on the chapter as a whole.

We break from Cobbett for much of the work, but in Chapters 16 (of Change of Species) through 20 (of Plows), we adopt much of Cobbett's philosophy: these cogent, well edited chapters are presented as the author intended them. They are the original work of Tull (with very minor grammatical editing by Cobbett) and their style is uniquely modern.

When, in those chapters, Tull breaks into commentary and discourse in conversational style, we decided it seemed more appropriate to keep that original language than in the expositions and essays of previous chapters. This was done not only for clarity, but also for artistic reasons.

A few notes of Tull's supplementary work were not added because they were highly redundant. Cobbett had left more out than we have because, presumably, they were relating to contemporary challenges issued to Tull and he might not have felt they were timely. Yet we included them, as they are instructive and the challenges contemporary to Tull. Such challenges have, unfortunately, again become relevant for Tull and his method.

An apology for excessive section subtitles, such as this one

Though no apology will be tendered for excessive footnotes, which were used (in Tull's own philosophy) of improving the readability of the work, we wish to apologize for excessive section subtitles. The reason for their employment was to incorporate some of that very practical vision of Monceau in making the work more useable.

An index to the work fails miserably. While it is a credit to Tull for presenting the integrated subjects governing the theories, practices and tools of agriculture in a way that allows a perspective of their independent and united relationships, it makes it very difficult to use as a reference. The employment of a table of contents seemed likely to address this issue, allowing someone to easily reference those subjects they had, in reading the book, been exposed to but wished to again read. It also serves Monceau's intention of simplification and summarization nicely, allowing a view of this enormous book "at-a-glance."

Yet there is little doubt that these notes somewhat take from the continuity of the work. Whether this is a fault or reduces the pleasure of the book is debatable, but we believed that it would enhance comprehension, memory retention and understanding by introducing concepts under a summarized title. And it is the feeling of understanding that is, ultimately, the greatest joy of this book.

Tull is still relevant, modern and useful

And this allows convenient segue into a brief discussion on how permanent and useful Tull's work is. Knowledge is more easily remembered than remade and so, unlike the third and fourth editions, all Tull's original work that survived is presented, all Tull's work has been amended by Tull's notes as Tull directed. The foreign languages have been translated to English, the English has been brought to modern standards of grammar and spelling. The Horse Hoeing Husbandry has been advanced, and entirely new sections have been added to describe the improvements to Tull's method and important agricultural technology, techniques and science that have been developed since Tull's

time, as well as some of the other crops that are important to the modern farmer. Tull's work itself has been updated through footnotes of the modern science that explains Tull's observations.

Margin notes by the Editors of the 5th Edition

The margin notes assume that the reader has an understanding of agriculture and that the reader is reading all the chapters in order: notes are only presented once, even if they serve to clarify many instances of the confusion over many chapters. The editors beg the reader to please forgive an unconventional notational style (in particular, the use of pronouns such as "I" or "We" and notes directed to "the reader"). We tried, as best we could, to be for the reader a guide to Tull's world, and this is not a solely objective role. Thus, the use of pronouns is kept to times when subjectivity is the goal, and the use of an impersonal "editor" is kept to times when objectivity is the goal. In all cases of this subjectivity, citation is used to identify the originator of the thought: A.B. for Aaron Brachfeld, M.C. for Mary Choate. When no citation is given, the note belonged to the original author: Jethro Tull.

Tull's language modernized while retaining character: Tull matures through his writings, becomes more conversational

We have attempted, in updating Tull's language, to preserve for the reader the effect writing had upon Tull: just as undertaking agriculture cultivates the farmer as much as the soil, so too does the act of writing civilize the human spirit. His earlier chapters and work reflect the genuine humility and timidity of a young lawyer writing a factual manual on agriculture, his later chapters and work reflect the confidence of an old master farmer as he transmits to posterity and the world something he knows is not only unique but essential to the long term welfare of humanity. His writing becomes more conversational as the work progresses, and though it begins in the manner of any technical manual, by the end, the text has the feel of a long talk with a new neighbor you have chanced to meet while he was working his fields in a most unusual way.

What an opportunity, to chat with Mr. Tull, first formally over the fence in a technical discussion, and then over tea as the implications of his new method are fully understood. Though we believe that we have done tolerably well in keeping Tull's voice in the work (even extending the style to the footnotes we have added to each chapter – to Tull, a margin note was as much of the text as any other words on the page), we encourage you to take the little effort of casting your eye to the original – and beautiful – language that was written in 17th Century England. To read the original Tull is to experience something truly beautiful happen. Cringe alongside Jethro Tull as you see his editor (for an inability to read his handwriting) leave some words b——. See what Tull keeps for his second edition intact, what he removes utterly. Look at the evolution of the work from simple gardening advice to the most significant work on agriculture and society to ever be printed. And observe how you, the curious reader, continue to encourage the further development of those efforts.

The New Deep Hoeing Husbandry

The deep hoeing method of Jethro Tull, while excellent in many ways, is not beyond improvement. Since 1997, we have endeavored to advance the Horse Hoeing Husbandry through an

application of the science and technology that has developed since Tull's time. The result has been the evolution of a new deep hoeing husbandry that is characterized by an active fallow, a combination of Tull's method with Eastern natural agricultural methods.

The Horse Hoeing Husbandry is defined by many practices, but most principally, 1) a matrix of aisles and raised beds that is tilled entirely before and after planting, 2) tilling the aisles regularly during the growing season, 3) herbicide through tillage in the areas of the beds between rows. A system to reserve natural resources for wildlife is included in the New Deep Hoeing Husbandry and aisles and beds are not rotated until spring so that plants can reseed and animals can survive. Animals, fungi and microorganisms are incorporated with the cultivation of plants, cultivation is undertaken on land and in water.

The New Deep Hoeing Husbandry requires studies in ecology and the natural sciences, and to the extent that they are required, such studies have been included and interfaced in Tull's scheme of Theory, Practice and Tools.

Excuse for lengthy quotations

The reader will forgive the lengthy quotations that are sometimes inserted. As this book is intended for, among many people, also farmers, and many farmers live in rural areas, some consideration has been made for their convenience: in Colorado and much of the United States, rural libraries are unable to provide many of the works cited here, and the difficulty that obtaining those citations for further study would be prohibitive to many readers. Thus, it has been necessary to attach them so that the reader may glean from them more than we could interpret on their behalf.

Praise for Jethro Tull

It would be to go too far to give Jethro Tull credit for modern agriculture because our modern understanding is the result of countless (and often forgotten or nameless) researchers and developers. Technological ("mechanized") agriculture, that foundation on which modern agriculture is built, being the product of scientific thought, would have been invented by a scientific person sooner or later if Tull did not do so. Yet it is no small praise to say it was Tull who invented the tools and discovered the knowledge required for mechanized agriculture.

It was Tull who was the first to apply the scientific method to agriculture. He was the first person to develop technological science. He is responsible for the invention of the seed drill, the practice of planting in rows, for working a team of horses (or oxen) in a single file line, for scientific pest and disease management, for long-term crop preservation until better prices are to be had, for encouraging the feeding of livestock in pens, and for encouraging the domestication of wild species whose virtues exceed those that are more commonly cultivated. It was Tull who then diffused his scientific methods among his neighbors and competitors for the betterment of humanity, who developed the techniques of agricultural education and who inspired the potential of agriculture to be used not only as a tool of foreign policy in war, but as the means by which to achieve lasting—and worldwide—peace.

The advent of mechanized agriculture is still as important now as it was when it was conceived—even if the progress made after Tull so much overshadows the birth of modern agriculture that the name of Jethro Tull is nearly forgotten. The infancy of a hero is overshadowed

by their adulthood, and yet we remember to cherish the infant from which our heroes sprung. We must remember to cherish the beginnings of our scientific age.

The modern reader is no less in debt to the giants that prepared the field for them than the giants who work the field today. When a modern reader picks up Tull's book, they can see the seed of the trees that shelter and feed them; the reader remembers the brave beginning of their modern way of life.

The lessons Tull teaches to a modern reader go far beyond agricultural theory. Tull should be praised because he sought in posterity an improvement to his art, not perfection in his own day. *The Horse-Hoeing Husbandry* is a book that boldly asserts science is an art of observation and worship, and proves beyond doubt that with patience and skill, many things are possible to understand. Like other works from the Scientific Enlightenment, it teaches that the nature created by the Almighty is fathomable by the sublime sight of science.

Tull's work is one of sublime science, a work that has a unique place in history, a work that is practical. From our ancient past, Tull has written a work that humbly demonstrates humanity's role within the world is one of worship through partnership—partnership with the plants, the animals, the fungi, the microorganisms and the world itself that is shared by every creature; worship through the restless wonder and study of the life with which we share this good Earth.

Tull's reasonable, logical, scientific and enlightened lesson is one that every subsequent generation of scientists reaffirm. His method is as reasonable for adoption today as it was when it was developed. Tull not only dug deep in his search for truth, but made the better tools with which his children and neighbors dug even deeper. What better praise is there for a great teacher than that?

Gratitude

We are in gratitude to all those who have helped in the creation of this edition, especially our teachers. We are especially grateful for the previous editors and publishers and the fine Latin translations of Justin Walker. Though we will not thank all our teachers by name here (there are simply too many of them), we hope they are honored by the humble thanks we give when we cite their magnificent works, or employ those important lessons they gave to us in our schooling.

We hope that this work itself renders sufficient praise to those teachers, friends and family who have helped us in our times of need.

We hope that what words we might now offer in gratitude inspire within the reader the desire to give thanks every day for the honor and joy of living. Sing, dance, let your body, mind and spirit be filled with joy at the honor of your work. Only have courage to do what needs done, and you will lack no strength, you will lack nothing you need to earn the honor due you.

We hope, by the binding of this book we fufill those promises we bound ourselves to when we promised to be of service to our fellow farmers, that they might be gifted with love and joy, that they may study their arts in peace. Reader, if this book serves you at all, render your thanks upon that which we love so dearly: treat all living things with compassion, for all your animals, plants, fungi and microorganisms are sentient and love you even more than we do.

We hope that the warmth of our intentions fulfill their promises, and that you will by them learn to render great glory unto that to which we owe do dearly our lives, that which we hope finds this work pleasing, that which we rely on yet to perpetually defend this work's authors and pages, its editors and students. We have always gotten what we needed when we needed it, we have

always given thanks, we fear only that we are incapable of expressing the full magnitude of our gratitude, hoping that our hopes and intentions suffice have been enough so that the the reader, in all their gardens, may

Dig Deeper
&
Break Ground Finely

—Aaron Brachfeld and Mary Choate
Colorado 2010

Theory of the Horse Hoeing Husbandry

Although I am satisfied that everyone who shall see as much of it as I have will be of my mind in this matter, I am aware that what I am going to advance will seem shocking to them before they have made trials.

Every man is best satisfied with experiments made by himself; therefore I advise him who intends to practice that he would repeat all my trials before he relies upon them—not because I have been unfaithful in the making or relating of any of my experiments (for I only made them in search of the Truth for my own satisfaction): I do not doubt that, if the reader follows the same process, their experiments will succeed as mine did. But by repeating the trials he may very likely draw many more lessons from them than I have.

—Jethro Tull

CHAPTER ONE:
OF ROOTS, SOIL AND COMPOST

OF ROOTS

Feeding plants is the purpose of agriculture, and feeding plants begins with roots

Since the feeding of plants relates to roots and since the feeding of plants is the most immediate use of agriculture, roots ought to be discussed in the first place.

Two divisions of roots: taproots and horizontal (fibrous) roots

Roots are very different in different plants but it is not necessary here to take notice of all the fine distinctions between them. Therefore I shall only divide them into two sorts: horizontal roots[31] and tap roots. Both groups have branching and fibers going all manner of ways to fill soil that is loose, but such roots as I call horizontal (except those of trees) seldom have any of their branchings deeper than the surface (their staple) that is commonly moved by the plow or spade. Tap roots commonly run down single and perpendicular, sometimes reaching many feet below the staple. This tap root has horizontal roots passing out all around the sides which extend to several yards distance from the tap root—though their minuteness and earthy tincture make them invisible to the unaided naked eye.

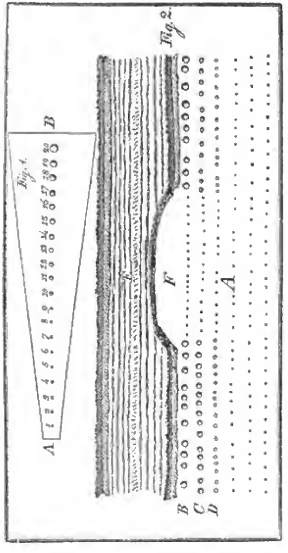
The distance to which roots extend horizontally learned by an experiment

By this method the distance of the extent of the roots of any plant may be discovered. [Please refer to Figure 1] Dig a piece or plot and make fine in whole hard ground, the smaller end (A) two feet and the wider end (B) twelve feet. The length of the piece should be 60 feet. Plant twenty turnips (labeled "1" through "20") at equal spacing. Hoe as closely as possible to the first plants with a spade and with each successive plant, hoe a foot further distance—six inches to each side. Make sure to dig deep each time, so that it will be the finer for the roots to enter when they are permitted to grow that distance.

If these turnips are all gradually bigger as they stand nearer to the end B, it is a proof that their roots extend so far from their center: if the turnip 20 is biggest, it is because it draws nourishment from all the land six feet from its center; but if turnips 16, 17, 18, 19, and 20 acquire no greater bulk than the turnip 15, it is clear that the roots of the turnips extend no farther than those of turnip 15 do (about four feet).

There is another way to find the length of roots. Make a long narrow trench at the distance you expect the roots to extend and fill it with salt. If the plant is killed by the salt, it is certain that at least some of the roots entered into it.

[31] These are now known as "fibrous roots," but for the clarity of Tull's explanation, we have retained his more visually descriptive term. –A.B. & M.C.


CHAP. I.—Of Roots.
Fig. 1.
A
B
Fig. 2
B
C
D
E
A

The length of roots learned by natural experiment

What put me on to this method was an observation of two lands drilled with turnips in rows, a foot apart, at very even intervals. [Please refer to Figure 2 on the preceding page] At both ends and one side was hard and unplowed soil. The turnips were not hoed and were very poor, small and yellow—except for the three outside rows (B, C and D) which stood next to the hoed soil (E). The soil E was hoed and harrowed at the time the soil A ought to have been and gave to the three outside rows (B, C and D) a very dark flourishing color. The turnips received so much benefit from it as to grow twice as big as any of the more distant rows. The second-nearest row C, being a foot nearer to the new plowed land, became twice as large as those in the further row D, but the middle row B, which was even nearer to the plowed land, grew much larger yet.

The land of hard unbroken ground (F) was about two perches[32] in length and about two to three feet across. It is remarkable that for the length of this interadjacent hard ground F, the rows B, C and D were as small and yellow as any in the land E. That the turnips in row D, about one foot distance from land E received a double increase proves that they had as much nourishment from the land E as from the land A on which they were planted. In their own land (A) their roots must have extended at least three feet or else they could not have reached the land E.

In pulling up the aforementioned turnips, their roots seemed to end at a few inches distance from the plants, but one cause of peoples' not suspecting roots to extend even to the twentieth part of the distance they actually do is from observing these horizontal roots near the plant to be pretty taper and assuming that if they continued to diminish at the rate they had until that point, they must soon come to an end. But the truth is that, after a few inches, the roots do not discernibly taper and pass to their ends very near the same bigness. This may be seen by experiment in growing roots in water.

Taproots have fibrous components, and plants undertake symbiosis with fungi and other microorganisms to graze upon foods and water otherwise out of reach, even from the atmosphere

Upon pulling up a carrot, I found an extremely small fiber on its side. It was much less wide than a hair, but through a microscope it appeared quite large. It was not taper, but broken off short at its end. It is probable that it never extended near as far as the turnip roots did. It had many fibers going out of it and I have seen that a carrot will draw nourishment from a great distance—though the roots are almost invisible where they come out of the carrot itself.[33] These fine roots, as demonstrated by the land F, cannot penetrate soil unless the soil is broken open by tillage.

[32] One perch is equivalent to a rod, which has the (approximate) modern length of sixteen and one-half feet. The distance of two perches, then, is about thirty-three feet. —A.B. & M.C.

[33] Through symbiotic relationships with microorganisms, a plant can increase its ability to draw nutrients from beyond its root zone: some of these microorganisms have long root-like structures to bring nutrients to their bodies (which the plants may either feast upon, or feast upon the wastes coming from those bodies), and some of these microorganisms are mobile, able to travel even to the surface to eat.

The ultimate extension of root zone can be seen when some microorganisms mineralize nutrients from the air that the plant could not, those minerals having evaporated from the oceans.

Roots seek loose soil

All roots—of trees and other plants—follow open soil. Roots can descend perpendicularly and mount again the same manner. In an orchard where the trees are planted too deep below the staple, the roots (at even a little distance from the stem) are all as near to the upper superficies[34] as those trees that are planted higher than the soil's surface. The damage of planting a tree too low in moist ground is that in passing through this low part the sap is chilled and its circulation is thereby retarded—not an inaccessibility to the staple.

I have observed the roots of a hedge to do this when passing a steep ditch two feet deep to reach the soil on the other side. When I dug five feet from the ditch, I found the roots there large—though this soil was very shallow and there were no roots below the good, open soil.

And I have seen a chalk pit (contiguous with a barn) the area of which was about forty perches of ground, was made clean and swept so that there was not the appearance of any part of a vegetable. Straw was thrown from the barn into the pit for cattle to lie on. The dung made thereby was carried

It is similar to how a penned cow's range can be extended by people and their vehicles, bringing hay from faraway lands during drought; similar to how ants will bring their farmed fungi food from faraway plants. Some of these microorganisms even interface directly with the plant's sap in much the way that animals rely on microorganisms in their guts to digest poisons and produce nutrients. Caring for these symbiotic partners of plants is as important as caring for the plants themselves; feeding the roots of plants begins by feeding the plants' symbiotic partners.

In an interview on National Public Radio by Robert Krulwich with microbiologist Glenn Gibson of the University of Reading in Britain on July 1, 2006, it was reported that bacteria alone outnumber the human cells in a human body. This does not include viruses, retroviruses, fungi, or other creatures in the human ecosystem. The importance of microorganisms to macroorganisms like humans, and their domesticated plants cannot be overestimated.

In their beautiful work, Plant Ecology (1929, second edition, 1938), Dr. John Weaver (of the University of Nebraska) and Dr. Frederic Clements (of the Carnegie Institution of Washington) discuss many valuable things, but also investigate the presence of soil organisms. "A single gram of loam from the surface soil may contain 14,000,000 to 58,000,000 bacteria, and in some soils even at a depth of 3 feet, as many as 37,000 per gram have been found. The mycelia [a rootlike structure] of fungi permeate soils, especially those rich in humus. The toadstools and puffballs of forest and grassland are most conspicuous, but hundreds of species of smaller, mold-like forms occur in countless numbers. Algae are frequently abundant. Protozoa are common in most soils, and sometimes a gram of soil may contain as many as 10,000 to 2,000,000 individuals. Many of these feed chiefly upon soil bacteria."

The soil microecosystem balances itself and protects the macroecosystem against disease. Life is interconnected from the microscopic to the macroscopic, and the feeding of plants must undertake consideration for these small creatures whose size has significantly limited our understanding of them and their "world." Yet, though the exact mechanics of these organisms is not well understood, Tull's method of deep hoeing tillage has worked for hundreds of years to feed them and care for them so they might feed and care for plants better. —A.B. & M.C.

[34] Superficies: surfaces. Jethro Tull uses the term to describe both internal surfaces and external surfaces. —A.B. & M.C.

away about three years after the pit had been cleaned when, at the bottom of it and on top of the chalk, the pit was covered all over with roots that came from a witch-elm that stood five yards above and six yards in length away from the pit. The witch-elm itself was only five yards tall, but in three years the roots grew themselves eight times the length of the tree beyond the extremities of the old roots. The annual increased length of the roots was three times as much as the height of the tree. I have seen this too in wheat: wheat, drilled, in double rows in November, in a field well tilled before planting, looked yellow when eighteen inches high. At two feet distance from the plants the soil was plowed. This gave such nourishment to the wheat that they recovered their health and changed their sickly yellow to a lively green.

Roots are like guts in animals, uptaking aqueous nutrition and expelling aqueous wastes

Roots are like to plants as guts are to animals. Roots are but as guts inverted[35] and bear that proportion to the stem and stalks of plants as guts do to the bodies of animals[36] (several times longer

[35] Soil is much more than the medium that plants grow in, just as food is much more than something to fill your stomach. Soil, like food, is filled with countless microorganisms and complex chemicals. Tull is correct to compare roots and stomachs, soil and food.

However, Tull was unable to know the full implications of this analogy. Changes in the food of people or plants can have a drastic effect on the types of microorganisms that live in a person's stomach or in the plant's soil. This change in flora affects the health of the person or plant: when a person eats too much protein in ratio to their sugars and fiber, bad microorganisms that produce toxins in the intestines flourish. The toxins are then absorbed into the blood of the person (a condition known as "toxemia"). A similar thing happens to plants when their wastes are unable to be digested and cleaned by friendly microorganisms. Compounding the toxemia, these toxins disrupt the ecology, and force the local wild creatures to find new sources of food—usually the plant that was being fertilized. A change in the diet of the plant or person also has a dramatic effect on the health of the individual.

In both plants and animals, the roots (or gut) not only uptakes aqueous nutrition (as the leaves, or lungs, uptake gaseous nutrition), but also expels aqueous wastes (as the leaves, or lungs, expel gaseous wastes). The solid nutrition and wastes must be suspended in water so that they are more easily moved by the cells of the organism.

Water also allows the body of the organism to more efficiently act upon a chemical: water divides atoms, molecules and especially salts so that their component atoms in a process called "dissociation." When salts are divided into positively charged and negatively charged ions (or "radicals") they are then nearly-independent atoms. In example, when the salt Calcium chloride is dissolved in water, an animal body can use both the Calcium and the Chlorine independently. Alternatively, if one component of a salt is toxic and the other nutritious, the body is free to undertake actions to dispose of one or the other, or may more easily dispose of both than if the salt were not suspended in water. For non-salts, water suspends their basic molecular and atomistic components so that they more easily be acted upon, or dilutes them so that they less easily act upon the body.

It is little surprise that life is largely water: it allows the multiple cells to communicate chemical and electrical signals together, and transfer the nutrients they require. –A.B. & M.C.

[36] An animal has but one gut, though its parts are distinguished by several names.

than the stalks). As animals of different species have their guts bearing different proportions to the length of their bodies, it is probable that different species of plants may have their roots in different proportions too. It is possible to know the length of the roots in the earth by those who would take the pains of more trials of examination, but this is enough for me: there is no plant commonly propagated that will not send out its roots far enough to have the benefit of the hoed aisles that I, in the following chapters, allot to them—even if they should not have roots as long as their stalks or stems.

The great length of roots allows them to eat from aisles

The great length of the roots will appear very reasonable if we compare the largeness of the leaves to the smallness of the capillary roots. The capillary roots must make up in length or number what they want in bigness if they are to range far enough in the earth to find a supply of matter to maintain the whole plant (whereas the chief office of the stalks and leaves is to only receive that matter and to discharge into the atmosphere such part thereof as is found unfit for nutrition[37]). This is a much easier task than the task of gathering matter and, consequently, requires fewer passages.

The leaves and stalks form an obtuse form—if they did not the air would be unable to sustain the stalks and leaves in their upright posture. But the roots, though very weak, long, flexible and slender, are easily supported by the earth.

Plants graze on moistened internal surfaces of soil, pressed against their roots; tillage increases pressure, surface area and moisture

In this the animal and plant bodies agree: the guts (and roots) are both injured by open air. Nature has taken an equal care that both may be supplied with nourishment without being exposed to the air. But guts are supplied from an internal surface and roots are supplied from an external surface, and so the food-in-water-suspension[38] that guts receive for the use of the animal is brought to them while the roots must search out and fetch themselves all the food[39] of the plant. This is why there is a greater quantity of roots (in length or number) required for plants than guts are required for an animal.

Roots are very much like the intestines of animals, and have lacteal vessels opening on their outer spongy superficies as the guts of animals have their opening in their inner spongy superficies. The animal lacteals absorb their food by the pressure that is made from the peristaltic motion and

[37] Here is a simplified process of sugar production in leaves that utilizes matter taken from the roots, discharging waste into the atmosphere: water (along with other minerals) is drawn by the roots and is brought to the sun-lit leaves by the stalk. The leaves combine the water with carbon dioxide from the air and the energy of the light, exhaling oxygen. While the simplified description presented here is accurate, it is accurate due to its abstraction. A more complex modern understanding of photosynthesis is, even at the late time of the publication of this edition, still incomplete and uncertain. –A.B. & M.C.

[38] Jethro Tull's word was "Pabulum," which means a food in suspension or solution suitable for absorption. –A.B. & M.C.

[39] Tull uses the word "food" to imply water as well as other matter. –A.B. & M.C.

that motion caused by the action of respiration—both of which motions press the mouths of the lacteals against the mass that is within the guts. Both these motions are supplied in roots by the pressure occasioned by the increase of their diameters in the earth, which presses their lacteal mouths against the soil without. But for such roots as those that live in water, a pressure is constantly made against the roots by the weight and fluidity of the water, pressing the fine particles of soil that the water contains against the roots.

When roots are in a tilled soil, a great pressure is made against them by the soil which is always subsiding and compressing food closer and closer into their mouths. Tilled soil can compress so much that the weaker sorts of roots cannot penetrate into it unless the soil is reopened by new tillage (a process we call "hoeing").

Demonstrating Circulation from the Roots of Sap and Chyle I: Experiments with Mints. Includes discussion on bioaccumulation of toxins, treatment of toxins by plants, animals and microorganisms, and insight into the way plants eat and drink[40]

That the color of the roots are different from the color of the leaves and other external parts of a plant is no argument against the circulation of the sap than to argue against a circulation of the blood by saying, "the color of the guts is different from that of the lungs and other parts of the animal body." As far as I can discover, all roots (if they are properly described) are white. Even the red carrot sends out in the spring from all parts of it many fibrous roots, all as white as those of any other plant. The white color of roots comes from the vessels that circulate the chyle to the other parts of the plant.

When a good number of mint stalks had stood in water until they were well stocked with roots from their two lower joints (some of them from the three lowest joints) I set one into a glass (marked "A") full of salt water. This mint A was perfectly dead within three days.

Another mint (marked "B") I put into a glass of fair water, but I immersed one string of its roots (being brought over the top of another glass) into another glass of salt water. This mint also died very soon[41].

Another mint (marked "C") stood in a glass of water and soil until it grew vigorously. I put one single root into a bag containing a spoonful of dry salt. Besides finding that this mint died also, I found that this salt was dissolved in water as high as the second joint of the root that was placed into it, and that the leaves of the mint tasted of salt.

I put a single root of another mint (marked "D") into a small glass of ink as I had done when I put a root of mint C into a bag of salt. This plant was killed by some of the ink ingredients, but the

[40] "Chyle" comes from the Greek word for "juice," and is intended by Tull to describe the solution of liquid drawn up from the roots (not yet circulated to the leaves or otherwise altered). –A.B. & M.C.

[41] Note that the effect of the salt was the same, whether all the roots or only one of the roots was grown in salt water. Plants cannot choose what they eat and only limitedly can choose not to eat. –A.B. & M.C.

blackness was not communicated to the stalk or leaves (which instead inclined to rather a yellowish color when they died, which seemed owing to the copperas[42] in the ink).[43]

[42] Copperas = Ferrous sulfate. It is commonly used as herbicide today, as a defoliant. –A.B. & M.C.

[43] Tull accidently discovers the potential for chemical herbicide, but does not think to use it (correctly) because it is more costly than a tillage system. No chemical is truly less costly than tillage, not only from its direct costs, but because of its secondary costs as well.

Every creature deposits poisons and heavy metals that cannot be broken down or excreted in "safe" areas and the deposition of the herbicide ferrous sulfate would be no exception. Plants will typically deposit these poisons in their leaves, because the plant can easily shed those leaves and save its life. Animals do likewise with their hair, feathers, skin, urine, fecal matter, but both plants and animals will sometimes store excess poison in fat cells and skeletal systems. Animals can store vast quantities of poison in their organs, muscles and bones.

Rachel Carson in her landmark work *Silent Spring* (1962) described the process by which poisons interact with a "food chain." A simplified example would go thus: poisons are consumed and processed by microorganisms, but excess poison is absorbed by plants. Plants destroy some of the poison, eliminate some of the poison untreated, and store excess poison. Herbivorous animals eat the plants and eat the poison in the plants. They eat many plants and get an excess of poison, which they neither eliminate or process, and store in their tissues. Carnivorous animals eat the herbivores, and get an even greater dose of poison. The poison is accumulated in the later parts of the food chain, whose members die of toxicity even while earlier components of the food chain live.

Carson spoke out against the fertilizers, herbicides and pesticides (which she called "biocides") that became toxic in the food chain warning that eventually, as more poison is added to the food chain, even earlier members of the chain would die, and that humans, being at the latest part of the chain, would be effected most of all. "'These sprays, dusts, and aerosols are now applied almost universally to farms, gardens, forests, and homes-nonselective chemicals that have the power to kill every insect, the 'good' and the 'bad,' to still the song of birds and the leaping of fish in the streams, to coat the leaves with a deadly film, and to linger on in soil-all this though the intended target may be only a few weeds or insects. Can anyone believe it is possible to lay down such a barrage of poisons on the surface of the earth without making it unfit for all life? They should not be called 'insecticides,' but 'biocides.'"

When animals eat poisoned plants or poisoned animals, they can sometimes also retain the poisonous chemicals. This "bioaccumulation" of toxins can be fatal. When the toxin is accumulated in one organism, and that organism dies, if it is not eaten by another animal, it will be degraded by microorganisms adapted to that specialized niche of eating those toxins. These organisms will break down the toxins into components safe enough for other creatures to eat. In this way, the radioactivity that was general on Earth for its early history was cleaned (sometimes, according to Lovelock and others, the bioaccumulation resulted in nuclear chain reactions and explosions!), and even fossil fuel or saline pollution can be cleaned. But it is foolish for the farmer to add fertilizers, pesticides and herbicides to the field if the microorganisms cannot process the quantities presented.

This results in a grave cost to the ecology. Numerous fertilizer, pesticide and herbicide agents are used, applied (after experiments modeled on Tull's that demonstrated a circulation of the chemical from an entry point) on the leaves, stems and roots of a plant. The circulation system of the

For another mint (marked "E"), I made a very strong solution of water and the bruised seeds of wild garlic. I placed a couple of roots into this stinking liquor. This solution killed the mint after some time, but it was much longer in dying than the others were when exposed to salt and ink. This slower death may be because these roots in the garlic were small and did not bear so great a proportion to their whole system of roots as the roots by which the other mints were poisoned did to theirs. When the edges of the leaves of mint E began to change color, I chewed some of them in my mouth and found at first the strong aromatic flavor of mint. But that taste was soon replaced by the nauseous taste of garlic, which was very perceptible to my palate.

I have observed with another mint (marked "F") that when mint has stood in a glass of water until it seemed to have finished its growth, the roots are a foot long and of an earthy color. When I put some fine soil into the water, it sunk to the bottom and soon there came from the upper joint a new set of white roots. These new white roots took their course on the outside of the heap of old roots downwards until they reached the earth at the bottom. Then they came to be of the same earthy color as the old ones.

Another mint (marked "G"), was well rooted from two joints about four inches apart. I put the roots of the lower joint in a deep glass of water and the roots of the upper joint into a square box of sand, which I had contrived for the purpose of standing over the glass of water: the box had a hole in it through which the mint stood, allowing the roots of the upper joint to be laid easily into one corner of the box of sand. The sand I filled the box with was first dried in a fire, but within only one night's time I found that the roots of the lower joint had drawn the water up and imparted so much of the water to the dry sand above that the sand that the corner in which the roots of the upper joint lay was very wet (the other three corners were dry).[44] This experiment I repeated very often and it always succeeded as it did the first time.

I prepared in my chamber a small trough (about two feet long) and placed a mint growing in a glass of water at each end of the trough (both marked "HH"). Half of the roots of each mint were allowed to stay in the water, the other half placed into the ends of the trough. I then covered the roots in the trough with loose soil and kept the glasses supplied with water. Whenever the roots would grow through the loose soil, I would put more on until the trough would hold no more. And still the white fibrous roots grew through the dirt, appearing above it. With a microscope I saw that these roots, upon coming above the ground, entered their ends into it again.[45, 46]

plant does bring these chemicals throughout their bodies, and a chemical will act on particular organs in particular ways.

The experiment with the poisonous ink would demonstrate to later generations a more significant understanding than Tull could have conceived. –A.B. & M.C.

[44] This is similar to how mint C moistened the bag of salt! –A.B. & M.C.

[45] Notice that this is similar to how mint F sought the soil at the bottom of the glass, and observe the behavior of plant roots when a new source of food is available! –A.B. & M.C.

[46] Plants react to adapt themselves to a changing environment as well as an animal (though perhaps not so fast); anticipating the behavior of plants is essential to their domestication and cultivation.

While the behavior of plants has been explored by many people since Tull's work, few have explored better than Charles and Francis Darwin in their book, *the Power of Movement in Plants* (published in 1895 by D. Appleton and Company). In their Concluding Remarks, the Darwins observe that,

These two mints (HH) in my chamber grew three times as large as any other mint I had that stood in glasses of water (which were many!) and much larger than those which stood in water with earth in it (those being of an equal bigness when they were set in)—even though these two mints never had any water in their earth but what their roots sent up from the glasses. There was such a vast quantity of water these roots sent up that it was sufficient to keep all the earth in the troughs moist, though there was a thousand times greater quantity of soil than the roots that watered it. It is probable that the water passed out of the roots into the earth without mixing at all with the sap or being altered in any degree[47]. The earth was always kept moist and even while in the hot weather there would not remain even a drop of water in the glasses after two days and a night, the roots in the glasses were never dry.

"if the tip [of the radicle] be lightly pressed or burnt or cut, it transmits an influence to the upper adjoining part, causing it to bend away from the affected side; and, what is more surprising, the tip can distinguish between a slightly harder and softer object, by which it simultaneously pressed on opposite sides. If, however, the radicle is pressed by a similar object a little above the tip, the pressed part does not transmit any influence to the more distant parts, but bends abruptly towards the object. If the tip perceives the air to be moister on one side than on the other, it likewise transmits an influence to the upper adjoining part, which bends towards the source of moisture. When the tip is excited by light (though in the case of radicles this was ascertained in only a single instance) the adjoining part bends from the light; but when excited by gravitation the same part bends towards the centre of gravity. An almost every case we can clearly perceive the final purpose or advantage of the several movements. Two, or perhaps more of the exciting causes often act simultaneously on the tip, and one conquers the other, no doubt in accordance with its importance for the life of the plant. The course pursued by the radicle in penetrating the ground must be determined by the tip; hence it has acquired such diverse kinds of sensitiveness. It is hardly an exaggeration to say that the tip of the radicle thus endowed, and having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense-organs and directing the several movements..."

—Chapter of Concluding Remarks, pages 572-573.

The Darwins' book is strongly recommended further reading –A.B. & M.C.

[47] Whether this water, so soon returned out of the roots, was at all altered during its short stay within the plant I cannot say until I see the results of an experiment: I should set half the fibrous root of a garlic (or other strong-tasting) plant in water and half of the roots in a trough of flour. If the roots in water send water to the roots in the flour, the flour may be tasted. If the flour tastes of garlic, then we know it is altered, otherwise we may conclude that the water is not altered.

Demonstrating circulation from the roots of sap and chyle II: remarks on the mints

Though some marine plants are in some ways fortified against the acrimony of salt, the mints A, B and C each demonstrate that salt is poison to other plants.[48] The reason why salts in dung, brine or urine do not kill plants in the field or garden is that their strength is diffused and weakened in the soil[49] so that the no considerable quantity or force of the salts reaches the roots.

I tried applying salt to many potatoes growing in the ground. I undermined them and put a few of their roots into a dish of salt water. These roots all died sooner or later (according to their bigness). By these potatoes and the mints B, C, D and E, it appears that roots make no distinction between nourishment and poison. And, they are not brought to ingesting poison for lack of nourishment—they were vigorous and well fed at the time when the most inconsiderable part of their number was exposed to salt, garlic or ink.

The mint F shows that when new soil is applied to old roots, a plant sends out new roots for the purpose of feeding upon the new soil. The more earth that is given, the more roots will be formed and the greater the vigor of the plant. This addition of soil corresponds with the action of hoeing: every time the soil is moved about the roots, it is as if they have a change of soil (though it is true the soil is not new, the soil that has been moved is new to them).

The mint G proves that there is such a communication between the roots so that when any of them have water, they share of that water with the rest.[50] This also demonstrates that the root of the lower joint of the mint had passages (or "vessels") leading from them (through the stalk) to the roots of the upper joint.

The circulation of sap and chyle accounts for the great produce of the plants with long tap-roots, such as alfalfa and sanfoin in dry weather: the soil at great depths is always moist, even if the soil at shallow depths may be dry. It accounts for the good crops of these plants we have in dry summers upon land that has a clay bottom, for in that clay bottom the water is retained a long time and the lower roots of the plants that reach it do like those of the mint G and send up a share of that water to all the higher roots. If those roots of a plant that lie at the surface of the ground did not

[48] Though there are many "salt tolerant" plants (especially in the oceans), these plants are, in fact, no more tolerant of salt than any other. The salt tolerance comes from an ability of the plant to safely store or eliminate the salt to avoid poisoning. –A.B. & M.C.

[49] When Jethro Tull says, "...or Urine, does not kill Plants in the Field, or Garden, is, that their Force is spent in acting upon, and dividing the parts of the earth; neither do these Salts, or at least any considerable Quantity of them, reach the roots," he tries to convey the concept that the salts are made weaker by being applied in the field. This can be explained by chemistry to be a kind of suspension or interaction of the salts with the water or soil wherein the salts themselves are split or altered...reducing their toxic effects, the activity of native chemicals on the salts in reactions that neutralize them, and also the actions of living creatures in the soil (many of the microscopic) that act upon the salts to neutralize them.

The word "diffused" earns the understanding that the strength of the salts is weakened by their acting upon not only the plants but the soil too, incorporating Tull's ancient (and correct) observation with modern understanding while not implying that a decreased density of salts is responsible for the phenomena observed. –A.B.

[50] Transportation of the water allows roots to bring the dry soil into a solution that the plant is better able to ingest. –A.B. & M.C.

receive moisture from other roots that lie deeper, they could be of no use in dry weather and when the dry surface is loosened or fertilized, the plant would not grow faster if no rain fell. The deep roots communicate a share of the water to the shallow roots and in return the shallow roots send a share of the food: the two mints, marked HH show that when the upper roots have moisture (as they had in the earth in the trough, carried there by the lower roots), they impart some of it to the lower when the lower roots require water.

Tillage encourages root growth both by breaking roots and by providing loose soil

These mints demonstrate the circulation of sap and chyle and explain the benefit of the hoeing effects: loosening the soil[31] encourages the plants to grow. Roots, by being broken off near their ends, increase their number and send out several where one is broken off, and roots increase their fibers every time the soil is loosened about them.

Jethro Tull's Supplement

Corn's first root not a taproot

In the manner of a taproot descends the first root of every seed, but corn has a very little one that goes no deeper than the earth is tilled. The first seed roots of corn die as soon as the other roots come near the surface above the grain, and therefore this first is not called a "tap root." The next roots that come out near the surface of the ground always reach down to the bottom of the pulverized staple, as can be seen if you carefully examine it in the spring time.

Migration of roots into a chalk pit

There is a chalk-pit contiguous to a barn, and the entire area of the chalk pit (being about forty perch of ground) was made clean and swept so that there was not the appearance of any part of a vegetable. For three years after the pit had been cleaned, straw that the cattle laid on in the barn was thrown into the pit. When the dung made by the cattle was hauled away at the end of those three years, at the bottom of the pit—upon the top of the chalk—the pit was covered all over with roots, which, upon further investigation, came from a witch-elm that grew not more than five or six yards from top to bottom, and which was about five yards above and eleven yards away from the area of the pit. It was thought that with this proportion of growth, the annual increased length of the roots was near three times as much as the height of the tree (so that, after three years the roots of this tree might extend themselves eight times the length of the tree, far beyond the extremities of the old roots—at eleven yards distance from the body).

[31] Loosening—not "loose"—soil. The difference lies in the process of loosening, which provides more benefits than loose soil: namely, the tillage encourages branching in roots, etc. These benefits (and others) are discussed in later chapters more in depth than this foot note should. –A.B. & M.C.

Proportion of roots

I am told a counterargument has been made from this account against the growth of a plant being in proportion to the length of its roots; but when the case is more fully stated, this objection may vanish: this witch-elm in question was a very old decayed stump (which in my neighborhood is called a stagger), which was formerly a plasher in an old white-thorn hedge wherein it stands. It had been lopped many years before that accidental increase of roots happened and, it being thus stunted, sent out poor shoots, and its boughs were mostly horizontally inclined. But in the third year, these roots the boughs were observed to grow vigorously, and the leaves were broad and of a flourishing color. And, at the end of the third year when all these roots were taken away, no more roots could run out on the bare chalk, and the growth of the boughs had been but little since.

Supplement of the Fifth Edition

Kinds of roots

Botanical science has defined the several kinds of roots. We have provided an identification guide, useful for identifying wild plants, but also for training the eye to recognize the different ways plants have adapted themselves and specialized their organs.

Modern botany also describes the morphology of underground energy storage tissues, and divides underground energy storage among root, stem and leaf structures: some plants have modified leaves or stems underground to store their energy in, and these modified organs begin to approach the function and appearance of roots. Also new to Tull, botany describes the use of roots as reproductive organs, wherein roots will travel above or below ground in making a clone of the plant.

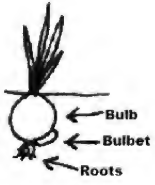
The best advantage to learning how to identify plants is that it requires the training allows an examination of a plant: consider what its shape is and what advantage the plant gains by that shape. Examine its role in the ecosystem, what creatures it interacts with, and you will, by training your mind to observe the various shapes there exist in all of nature, understand what advantage that specific shape has to offer in this case. There are a limited number of variations, and each serves a purpose both to the plant directly, and to the environment of the plant to aid the plant indirectly.

Study, as Tull did, the lineage of each plant: where it originated, its relatives and ancestry, and see how a solution from eons past has new practical applications for a modern individual.

Tull's definition between tap roots and fibrous roots remains a fundamental division: plants use their roots to eat and drink, and will often specialize in one or the other. Those that live in dry environments or are native to environments with a deep layer of top soil will have tap roots so that they may either drink from the moist depths or better consume the deep rich soil, and those that live in moist environments or are native to environments with shallow top soil will have branching, shallow roots.

Taproots are energetically expensive undertakings and only made upon need and there are many reasons a plant would need them.

- **Bulb** – a round underground extension of the leaves and stem. When cut, layers of leaves are often visible (like an onion) The roots are located below the bulb. Bulbs are typically used as nutrient storage.
- **Bulbet** – a small attached division of a bulb that produces shoots for new plants



- **Corm** – a thick, short root for storage of nutrients



- **Fibrous** – Thin, branching, usually with no primary root



- **Taproot** – a thick, long root for storage of nutrients and penetrating deep into soils to access food and water



- **Tuber** – a fleshy root for storage of nutrients that also has reproductive functions when it produces shoots for new plants



- **Rhizome** – a root that undertakes reproductive functions when it produces shoots for "new" (clone) plants (sometimes called "suckers")



- **Stolon** – an above-ground rhizome, sometimes called "runners"



OF SOIL

Behavior of roots in seeking food and water, need for great surface area of roots

Doctors Weaver and Clements (*Plant Ecology*, 1929, 1938) measured the length of plant roots and found that it is not only their reach in their search for food but the density that matters to total plant growth. A mature oat plant can have a total length of roots (excluding the microscopic roots which could not be measured) exceeding 54 miles: this increases the surface area of the microscopic roots considerably, so that the plant can obtain as much food and water as is necessary for its growth.

This is not unreasonable: Tull understood the minute divisions required for plants to eat, and the immense surface area and soil volume required to feed a plant. In comparison, the human body also requires an immense surface area when eating (or breathing):

	Surface Area (square feet)	Volume (cubic feet)
4.9 foot tall Human Child	6.56	0.2624
Their Lung	328.08	0.0328
Their Intestine	984.25	0.0328
Source: Mitchell N Charity, Mass. Inst. Tech.		

This is because the transfer of nutrients into the body occurs at or almost at an atomic level, and the cells which undertake the transfer must each have direct access to the air or food and, to function best, each must have a large surface area exposed to the air or food if they are to feed not only themselves, but every other cell in the body.

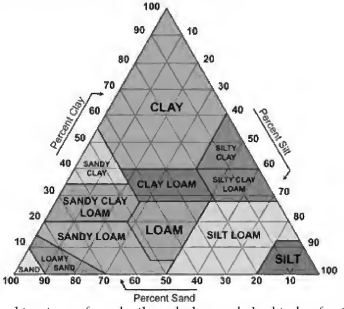
Importance of soil to roots

Because plants use roots to most directly interface with soil, discussion on soil will be included in this chapter.

Composition of soil: solid, liquid and gas ; sand clay, silt and humus

Doctors Milo Harpstead, Thomas Sauer and William Bennett in their *Soil Science Simplified* (1980, 1988 and 1997) describe soil as a three-phase system of solids, liquids and gasses, each of which is essential to the health of plants. "The solid phase is made up primarily of minerals along with a small amount of humus in most soils. This phase provides a source of nutrients and anchorage for plants and makes up about 50% of the soil volume. The liquid and gaseous phases occupy the other half, and the proportion of each varies as the soil gains or loses moisture."

The mineral portion of the soil consists of sand (particles between 2 mm to 0.05 mm, divided into 5 classes of very fine, fine, medium, coarse and very coarse sand), silt (particles between 0.050 mm and 0.002 mm) and clay (particles smaller than 0.002 mm).



Soil is divided into combinations of sand, silt and clay, and the kinds of soil are named by their various compositions: loam, which is ideal for most plant life, is 40% sand, 40% silt and 20% clay.

However, some plants do better in sandy soil, which drains easier and is easier for roots to penetrate. Others do better in clay soils, which hold water, are difficult to penetrate but full of nutrients.

All plants prefer a soil rich in humus, which is organic matter. Humus is easily formed through Tullian methods, as it consists largely of soil microorganisms and the byproducts of soil microorganisms, which are encouraged through tillage, and the resulting water and air.

How soil is formed, kinds of soil, importance of humus to tillage; tillage creates humus

Soil is formed by several factors and in several ways. Parent material, or bedrock, is either slowly broken up at a site or brought there by water and other agents of the climate. The climate treats the parent material (which has little variation throughout the world) in different ways through warming, cooling, wetting, drying, freezing and thawing to "soften" the bedrock. Oceans also do much to prepare bedrock. As topography develops, the influence of weather diversifies the soil: hills shelter some areas from weather, and expose others more to it. As soon as the weather has sufficiently treated the bedrock, life pioneers it and begins to speed up weathering. The first pioneers are typically microorganisms, but lichen are also sometimes among the first present on the rock and new soil.

However, bedrock is sometimes formed through volcanic action, which will rain down ash or lava.

Sometimes, too, bedrock is formed through the actions of coral, which precipitates calcium out of the seawater to form a kind of bedrock. Other living creatures will form bedrock too by precipitating matter out of water as well.

Glaciers and wind do much to create topography, but can do little to affect the nature of the soil. Limestone will typically result in clay soils and granite bedrock in sandy soils no matter how much weather treats the bedrock.

As soils mature from bedrock to soil, they become less dense and develop soil structural types. Granular soils (typically in dark surface soils), platy (typically in pale subsurface soil), blocky (typically in clay-enriched subsoil in forested regions), prismatic (typically in grassland subsoils) and columnar (typically in sodium-affected subsoils in grasslands). These structures are based on the molecular compounds that form the sand, silt and clay of the soil. Tull describes land as light, heavy, chalky, or with other descriptors, and while these are accurate descriptions of the conditions he was facing, they are not scientific classifications of soil and it is impossible to say how to classify his soil description using modern soil classifications.

Yet it does not matter much that Tull was not using modern scientific classifications. As the soils mature into humus, these structural types become insignificant to the farmer and become even less dense.

Important to the Tullian farmer especially, humus allows easier tillage as it does not clod and is not so sticky. The more the soil is tilled, the less sticky and cloddy it will become. If tillage is undertaken properly, the farmer encourages the growth of the microorganisms that build humus. If not, it will destroy humus and make tillage more difficult.

Necessity of microorganisms to animals and plants

Tull compared the stomachs of animals to the roots of plants, and was not the only one to understand things so: Dr. J. H. Kellogg, of the Battle Creek Sanitarium, through his experiments and in coordination with Louis Pasteur, discovered a similarity between the digestion in the animal stomach and the fertility of the soil and reported it in his landmark work, *Autointoxication*: "Food is to the body what earth is to plants. The food is the soil out of which the body grows. The four million villi of the small intestine are the rootlets which suck up the nutrient material prepared by the digestive ferments to nourish the tissues"

Dr. Kellogg explains that, whether in agriculture or in medicine, microorganisms can be helpful or hurtful. However, under correct conditions, microorganisms can be as helpful to plants as, under correct conditions, microorganisms can be helpful to animals.

Microorganisms in the soil can improve the fertility of the soil (and improve the ability of plants to benefit from what fertility there is already within a soil), and that access to Oxygen, water, Carbon Dioxide, Nitrogen, and other atmospheric components aid these microorganisms.

"The rootlets of plants are surrounded by bacteria that perform a useful office for the plant by fixing the nitrogen of the air and converting it into compounds that the plant can use in the manufacture of protein and plant protoplasms. Bacteria are evidently necessary for the promotion of plant life through the making of soil and the fixation of nitrogen, although it was long ago shown by the Pasteur Institute that some plants may grow in a perfectly sterile medium." (*Autointoxication*)

Many animals and plants rely upon microorganisms for their nutrition, and many more animals have a decreased nutritional uptake and digestion efficiency without nutrition: a ruminant would be able to survive upon a very modified "artificial" diet if it had no microorganism in its stomachs, but

would find it difficult or impossible to survive on its natural forage without the help of microorganisms. Even humans would be hard put to feed themselves without the digestive aids and protection of alimentary microorganisms. Plants rely upon bacteria—or else upon the artificial diet provided by their human caretakers.

Bacteria also provide defensive services to plants and animals. By competing with microorganisms that are harmful to the plants and animals that feed them carbohydrates, the "good" bacteria produce acids that destroy "bad bacteria." Generally, "bad" bacteria feed upon proteins and Kellogg demonstrates that improved health results upon reducing proteins in the diet. But this research has implications for plants, as well:

"Certain bacteria, like the nitrogen-fixing bacteria of the soil, require a large amount of carbohydrate...on the other hand, many bacteria thrive best when supplied with a culture media containing an abundance of nitrogenous substances in some form. These organisms in turn give rise to a destructive change that in organic substances is known as putrefaction. Instead of acids, this class of bacteria produce ammonia, ptomains, skatol, indol, phenol, or carbolic acid, and other highly poisonous substances, among which are tox-albumins, which closely resemble and sometimes exceed in virulence the venoms of the most poisonous reptiles. Some of these nitrogen loving organisms are able to decompose native or raw protein...

...Notwithstanding the prodigiously mischievous effects that are justly attributed to the action of bacteria, it must be admitted that they are essential in the economy of life. It is only through the action of bacteria that the great cycle of vital activities that constitute the organic world is made possible. For example, the soil from which plants grow owes its origin to the action of bacteria. It is through bacteria growing in the soil that the nitrogen of the air is fixed and prepared for the use of plants...No better illustration of the prodigious activity of microorganisms could be offered than the observations of Muntz and Lainé who found that a peat bed 6.50 feet thick and covering an area of 25 acres, if inoculated with nitrifying bacteria, might be made to produce the enormous quantity of 1,500 tons of nitrate daily...except for this beneficent action of the bacteria the soil would sooner or later become exhausted and the earth would be encumbered with the desiccated forms of plants and animals which had finished their life history...

...Fermentation and putrefaction are antagonistic processes. Fermentation produces acid products which are for the most part harmless to human beings [and plants –A.B. & M.C.] *but inimical to putrefactive bacteria...*

Thus, milk (because of the great quantity of sugar it contains) ferments and sugars of all kinds can preserve protein sources against decay. It is the principle that allows silage and cheese to retain their nutrients for later consumption. Importantly, it is also the principle that allows tillage to reduce not only the destructive "bad" bacteria and their poisonous wastes in the soil, but also provide better food for plants.

Bacteria outnumber human cells in the body, and the body relies on microorganisms for active and passive defense. Plants are no different in this respect: the human body relies upon the actions of "helpful" microorganisms for nutrition, and so should humans rely on microorganisms for the nutrition of their plants: Tull's method encourages feeding the soil to feed the plants; Dr. Kellogg suggests the feeding of the stomach to feed the animal; why not feed the soil, as Tull suggests, to feed the plant? Dr. Kellogg's book, *Autointoxication or Intestinal Toxemia*, is strongly recommended further reading.

How plants feed Oxygen to microorganisms they depend upon and release Carbon dioxide into the soil to make eating easier for themselves, the creation of humus by plants and burrowing animals and how humus makes eating easier for plants

Plants will exhale Carbon dioxide through their roots. This will make the soil slightly acidic and aids in dissolving plant nutrients and helps the plant take up those nutrients (Harpstead, Sauer & Bennett). Plants also exhale Oxygen, which helps in the precipitation of iron and other oxides (Harpstead, Sauer & Bennett), and provides the necessary oxygen to the microorganisms the plant depends upon for safety and food.

Humus, slightly negative in charge, also helps plants eat, and as their leaves fall to the surface of the soil and are dragged underground by worms, insects, prairie dogs, and burrowing creatures of all kinds, plants form a humus that makes it easier for them to eat, a humus that retains water better than the native soil, and otherwise makes life easier for the plant.

Yet the farmer who would till the old vegetation under, or apply green manure, or even just till the ground itself without any vegetable matter on it, does as much or more to build humus!

Humus does even more for plants and the microorganisms it needs. It binds with Calcium and Potassium readily (each of which are slightly positively charged) and holds them in place against rain and precipitation so the plant (and microorganisms) can eat them when they are needed (Harpstead, Sauer & Bennnett). Humus binds with poisons, as well, and can neutralize them, allow microorganisms to destroy them easier, or can act itself as a buffer against them (Harpstead, Sauer & Bennett).

Humus, in this way, also protects plants against "acid rain" pollution, which is rain charged with sulfuric acid resulting from the burning of coal and fossil fuels. However, too much acid rain, or too slow of a humus-building process, and the humus is destroyed by acid rain.

Origins of Nitrogen, Phosphorus and other necessary nutrients from tillage; the farmer who undertakes Tullian methods never needs to add them to the soil

The farmer who undertakes Tullian methods never needs to add Nitrogen, Phosphorus and other necessary nutrients to the soil.

Nitrogen is plentiful in the atmosphere, which is about 78% nitrogen. Some bacteria (especially the famous azotobacter, which free-living bacteria, and the rhizobia, which are symbiotic to certain leguminous plants) can mineralize the atmospheric nitrogen into a form useable by plants. Rain, too, carries some of the nitrogen from the atmosphere to the soil.

When creatures die, their proteins (which contain great quantities of Ammonium (NH_4^+) enter into the soil. While most plants do not eat Ammonium well, some bacteria (the nitrosomonas bacteria) eat the Ammonium and gain energy by oxidizing it into Nitrate (NO_2^-). This Nitrate is good food for other bacteria (the nitrobacter bacteria) which transform it into Nitrate (NO_3^-), which is good food for plants.

Certain fungi and bacteria can release phosphorus from mineral particles during the ongoing weathering process (Harpstead, Sauer & Bennett). They produce carbonic acid, lactic acid, nitric acid, sulfuric acid and others that dissolve bedrocks, sand, silt and clay to release important nutrients for life: as small as soil particles may be, their atoms may yet still be liberated to feed plants!

All these beneficial microorganisms are promoted through tillage, which increases oxygen and water in the soil.

How humus prevents water from carrying away nutrients

In inorganic soils, larger particles do not hold on to the nutrients and allow water to percolate at fast velocities that carry the nutrients far away. Smaller particles reduce velocity, but also prevent the water from infiltrating in the first place. The natural chemical adhesion and cohesion of the soil affects its ability to retain water and retain nutrients. When water runs through a soil, it can strip the soil of its nutrients.

Humus, binding to the nutrients and slowing the percolation without interrupting the infiltration of the water, helps protect soil fertility. Humus also improves the storage of water in the soil.

Implication for irrigation: gradual introduction of great quantities of water, either by sprinkler or by basin

When irrigating, it is important to remember that the infiltration rate of water (the rate at which it enters the soil) decreases as the soil wets (Harpstead, Sauer & Bennett), so it is better to water a little bit at a time. Also, the more water there is in the soil, the less quickly it evaporates, so it is important to irrigate a lot at once. The resulting need is a gradual introduction of water onto the soil and the deep saturation of the soil.

While flood irrigation is a typical system, sprinkler irrigation allows for this gradual introduction of vast quantities of water into the soil. For those farmers who must rely on ditches and flooding, it would be wise to force the water to remain on the soil surface until it has saturated by elevating beds above the aisles and holding the water in the aisles like ponds until all the water is absorbed. This is called "basin" irrigation. The beds during this irrigation appear to be islands, and the farmer who would use this would be smart to provide a boardwalk and bridges in critical areas to avoid losing boots in the soil.

Doctors Harpstead, Sauer and Bennett prefer dikes when aisles are inclined. "A principal point to keep in mind is that in many cases it is desirable to keep as much of the water as possible where it falls or is applied by irrigation so that it can move into the soil and be used by plants...contouring and strip cropping are techniques...another approach is furrow diking, which is an old practice...a dike is placed in each furrow at intervals of 6 to 12 feet with a resulting depression holding water between the dikes. This greatly decreases runoff and improves plant growth."

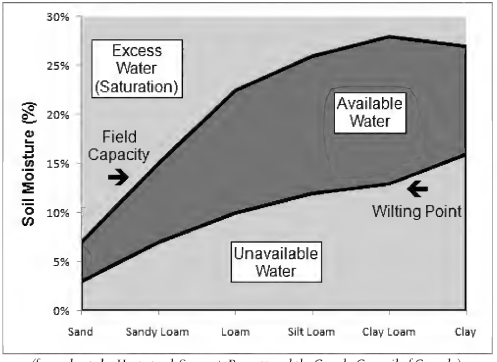
Standing water, whether flooded or in a basin, will compact the soil. Sprinklers also compact the soil. But, this is little concern to the Tullian farmer who tills the aisles regularly.

Run off should be avoided, as this reduces communication between the soil and atmosphere through the creation of crusts and carries away nutrients and soil, possibly exposing roots to the deadly air.

To see how well water is penetrating and retaining, dig down several feet with a shovel to observe conditions periodically after watering.

Soil water content versus available water

Plants penetrate different soils with more or less ease, and different soils hold more or less water. As a result, each kind of soil has not only measurable soil moisture content, but also available moisture content. Available moisture is divided between two ranges of wilting point and field capacity, describing the points at which plants generally suffer from too much or too little water. While some plants tolerate too much or too little water better than others, these points define the beginnings of excess (or "gravitational") water and unavailable water. When soil can retain no more water, it is "saturated."



(from charts by Harpstead, Sauer & Bennett and the Canola Council of Canada)

Sandy soils are apt to have either too much water or too little, and while clay improves the water capacity and availability in the soil, a pure clay soil is less good than a clay loam.

Need for mulch in winter and other times: reduces evaporation, stabilizes temperature, provides food and shelter to friendly micro and macroorganisms, provides more soil moisture through condensation

Mulch reduces evaporation of water while not inhibiting the percolation or infiltration of the water (Harpstead, Sauer & Bennett). Many trees naturally lay down a healthy mulch of leaves every autumn before winter: this keeps the soil not only warmer (and the friendly microorganisms more active), but also reduces evaporation to retain water for the spring when the tree will need it again. Evergreens also lay down a thick layer of leaves, but do so all year long.

Fields that allow debris to stand all winter long in the beds not only provide necessary food and shelter to the friendly micro and macro organisms their plants rely upon, but also retain moisture for the plants to enjoy in next year's aisles (when the beds and aisles are shifted annually in the spring). Debris reduces evaporation of snow and water by wind and by sun.

Mulch also stabilizes temperatures by insulating with air the soil against excess incoming solar radiation and excess outgoing heat radiation.

This air also acts to encourage the precipitation of dew, by providing a temperature and pressure difference by which atmospheric water will condense, similar to how tillage creates air pockets for water to condense into. This increases overall soil moisture.

Erosion cautions: while zero or negative erosion is usual, caution should be taken to ensure that erosion does not occur during heavy rains or winds

As water runs off or when wind flies across the surface of the field, they can strip a soil of nutrients and it can also strip a soil of its mass. When wind and water begin to take more soil from the ground than is naturally replenished by the actions of the farmer and other living creatures, "erosion" occurs. Typically, if the farmer undertakes good management, zero or negative erosion will occur as the soil is built up. However, cautions can be taken to ensure that erosion does not occur during heavy rains or winds.

Ensure that water drainages on the farm are well vegetated, especially along their edges where they meet the fields: these plants will slow the flow of water and capture the soil leaving the farm. On hilly topography, do as Tull advises in subsequent chapters and plant rows to follow the contour of the hill in gradual or zero-grade slopes.

Allow strips of vegetation to grow all year long to reduce the powers of the wind at the surface of the field. This is easily accomplished by reserving 20% of the field in natural wilderness (by allowing every 5th aisle/bed pair to remain wilderness), by planting hedges of edible trees and bushes, or both.

The Tullian farmer who does not allow every 5th aisle/bed pair to remain in wilderness and who does not plant hedges of edible trees and bushes faces the greatest danger of erosion in the spring, after last year's beds are tilled and the new beds are not yet grown in because vegetation slows down the rate of surface water and wind flow. Planting edible hedges and fruit or nut orchards among the crops will do much to reduce or eliminate erosion risks in spring. If planned properly, these trees and bushes also reduce or eliminate the risks of wind erosion.

In doing so, planting densities should, of course, be observed: planting trees and bushes too close to crops is a hazard to all the plants considered, but successive polycultural intercropping is both possible and advisable for the long-term maintenance of land and the long-term profitable interests of the farmer.

The farmer who would not plant trees and bushes should layer the ground with a mulch of straw, hay or other debris during this critical time. We have undertaken experiments and found that putting such a debris layer down following planting successfully overcame the erosion risk. In this way, even shifting sands in dunes or the running waters in a creek can be held in place long enough for irrigated plants to take hold of them and provide sheltered places in the sand for microorganisms to build humus. With the mulch, neither the wind nor the rain can move the particles of soil from where they are: the surface debris holds the soil in place. While some

conditions will require heavier debris (such as logs or branches of trees or leaves) in many conditions straw or hay will do fine.

It makes sense to raise a crop of hay or straw for this purpose, but trees and bushes will produce much more debris at less cost: hay is better produced for animal feed.

While deep mulches are better, experiments under the conditions of your farm will demonstrate how thick is absolutely necessary.

For perennial crops when beds and aisles do not shift (such as alfalfa, sanfoin, etc.) this precaution against erosion is usually unnecessary: there is (usually) sufficient debris on the field and sufficient roots beneath the ground to reduce the risks of erosion, but the farmer ought to still vegetate waterways, and would be smart to consider trees as well.

OF COMPOST

Composting is a method of manufacturing humus through waste recycling. The humus is then, generally, applied to the soil as an amendment, if it is not manufactured on the soil itself.

Compost is effective and useful waste recycling

Farm production results in a variety of wastes biological wastes. Animals produce manure after eating, shed feathers and skin, gasses are produced; plants lose leaves, produce damaged fruits, produce waste vapors.

The interests of resource efficiency urges the farmer must attempt to recycle wastes.

An example of recycling is using plant scraps from the field as food for animals: the scraps reenter the production cycle as food. Another example is plant material in excess of what the animals can eat being tilled under as green manures.

Yet there are some wastes which cannot be either fed to other animals. Some plants are poisonous to some animals, for example. Another example is found in the carcasses of dead animals, which are a hazard to the people who would eat the produce from the field fertilized by those bodies. The most important example is in manure, which would be dangerous to apply to the field as-is. Manure, whether it comes from human or animal sources, is full of an unbalanced community of microorganisms and can make the people who would eat the food sick if not properly managed and, while manure is stronger when fresh, it is inappropriate for use in the growth of plants intended for human consumption.

Putting raw manure on crops is a good way to poison the people eating the crops. Because of this, some farmers will simply bury the waste. But this inevitably leaches into the drinking water of the farmer or the water table of the crops, and accidents to the waste disposal site can have disastrous implications. Septic systems are little better than a simple burial. Some farmers will dump their manure directly into a nearby river or lake, but putting it directly in the fresh water supply of a farm is worse than letting it find its way there through percolations of the ground. Dumping into the ocean is equally bad: festering there, the waste becomes a toxic threat to the land on which the farm resides.

Composting produces saleable product

The best way to manage waste is to compost it. Not only does this render the waste safe, but it also can produce a soil-amending product that the farmer can sell to other farmers or to gardeners.

Composting may have primary and secondary treatments

Composting is undertaken through the actions of microorganisms, though secondary treatment by worms in vermaculture is beneficial. Secondary treatment of manure by fish in aquaculture is impossible: while fish can be relied on for primary treatment of manure and waste from chicken coops or animals can be made to fall directly into the water or placed into a feeding bin in the pond, composting waste before it is fed to fish, while reducing the risk of disease to the fish, also renders the waste nearly inedible for the fish: the fish eat the undigested portions of the manure.

Composting ideal for human wastes as well

Composting is a good way to deal with human sewage and wastes. Not just fecal wastes, but kitchen wastes, office wastes and other trash as well. We have undertaken trials and have found that all kinds of organic materials, paper products, cardboards, various plastics, petroleum jelly, gasoline, machine grease, diesel fuel, and, really, any kind of waste we could imagine have composted well.

Composting detoxifies a diversity of wastes when a diversity of organisms are acting upon it

The reason for this is because there are very many microorganisms in a wild community, and whatever food is presented to the community, there will be one or more species that will enjoy it with gusto. In fact, even uranium is delicious to some microorganisms!

The cultivation of composting microorganisms is easy: give the community food, and the microbe best suited for its digestion will find it and eat it. You do not have to police the numerous organisms: the numerous species (generally) do not produce toxic byproducts dangerous to their neighbors, and the compost pile can compost not only diverse kinds of waste simultaneously, but can radically shift what it is digesting quickly.

By microorganisms, we include bacteria, fungi, viruses and retroviruses. This is because sometimes the primary consumer of a waste must themselves be eaten and digested before the waste is fully processed.

The result of composting is the most healthful, non-toxic soil imaginable.

In fact, compost can also be used as a filter for water or air: put the polluted air and water through a growing media suitable for microorganisms, and they will eat the toxins in the air and water, as they eat from the atmosphere and waters naturally.

A sterile soil or sterile water is dangerous: the more microorganism biodiversity in the soil, air and water, the healthier the soil, air and water will be: the microorganisms keep each other in check, in a balanced ecological community.

Methods: composting is a process of fermentation, controlling humidity, sugar, nitrogen and other factors is important for quick composting; for slow composting, environmental control matters less

Composting is similar to the processes of making yogurt, wine, beer, bread or any other microorganism culture. Give them food, air and water, and leave them alone.

Providing the compost heap with including bulky items can trap air (no need to turn a pile!), providing water when the pile gets too dry (below 40% moisture) and providing adequate drainage to prevent the pile from becoming too moist (above 60% moisture). However, if it gets too moist or too dry, do not worry: the communities are still hard at work, but will not be working at peak efficiency.

While there is little need to keep the pile from becoming too hot or too cold, some people do by using blankets, heaters, shades and all kinds of heating and cooling systems. The microorganisms generally will work best in temperatures that are neither too hot nor too cold, and allowing for a somewhat longer composting schedule (1 to 2 years) will reduce the need for babying the compost.

Occasionally stirring or turning a pile does help, but is not necessary.

Inoculation of compost pile with "starter" colonies of microorganisms obtained from soil sample or other compost bin

Nature takes care of providing a plethora of biodiversity. To encourage biodiversity, shovel a few scoops of garden soil or finished compost into the compost bin as "starter."

We find the best success with mixtures of even 25% soil, and 75% waste. The more soil, the quicker the composting will happen. The smaller the size of the waste when it is put into the compost bin, the quicker it will compost: the more it is chopped, the more surface area there is for microorganisms to eat from.

Media is sometimes required to accompany starter

Wood chips are also great media for the microorganisms to get a boost from. In composting human manure, we recommend wood chips, tree leaves, straw or other organic matter at ratios of even 25% human manure: this will speed the composting and reduce undesirable odors. Air, sunlight and the competition of the compost community will make most of the dangerous microorganisms in the human manure safe, but it is important still to keep pets and animals away from the bins.

Another boost is organic material that is left to rot for a little while and then added to the compost.

Separating human manure is not necessary, but good for business

We separate out our human manure from other compost material. This is not done for safety issues (human compost is very safe), but because customers who buy our food do not wish to think

about human manure on their food. The composted human manure is applied to those plants which are not sold to customers, or applied to hay and pasture.

In ground composting through Tullian tillage

Tullian tillage is a form of composting. By adding air and moderating temperature and moisture, it allows microorganisms to do their job and compost what is on and under the field. We have rented fields polluted by any number of toxins, including fossil fuels and herbicides, and tillage has cleaned them up. We did so not out of the challenge of the field, but because these fields were cheaper. While many of our landlords were supportive, some of our landlords were impressed enough to want their "waste" land back, terminating our rental agreement prematurely. The strategy of obtaining cheap lands and reclaiming them is better accomplished when you are the landowner, or have sufficient contracts with the landlord to allow your investment towards reclamation to be compensated.

Tilling regularly and treating your soil like a compost heap also results in negative erosion. The creatures in the soil will mineralize (a word describing the transformation of a gas, liquid or plasma into a solid) atmospheric chemicals like nitrogen, carbon, oxygen, phosphorous, potassium, etc. and build soil. We usually experience negative erosion on our fields. Our greatest negative erosion rate was 1 inch every year for two years before our landlord wanted their land back.

An added benefit is that the biodiverse community in the soil prevents any one kind of bacteria, fungus, virus or protovirus from becoming too numerous and polluting the environment with its special kind of waste. The stable state of the microecology results in the ideally balanced nutrition for plants (because plants adapted to eat from healthy soils).

Some microorganisms eat the wastes of bacteria, fungi, viruses and protoviruses.

Though there are countless sources for further reading on the subject of soil science and composting, the very best is the authoritative *Humanure Handbook*, by Joseph Jenkins. It contains valuable and easy to understand information on composting for every family's needs, reviews of other books, essential chemistry explanations, instructions for construction of various tools and machines, and beautiful illustrations.

Composting in bins

Compost bins are easily constructed. We prefer bins built out of wood because they "breathe" better than stone, but have used stone bins to satisfaction. Bins can even be made by piling small branches in a square!

The very best and most affordable way to build a compost bin is by using wood pallets. These are used to help forklifts manage odd shaped or heavy containers (see Picture 1)



Picture 1: A Wood Pallet

By screwing them together, a small, 4-sided structure can be built above the ground. Some prefer to put a "floor" pallet above the ground to decrease moisture content, but in dry places a floor is detrimental. Besides, a lack of floor allows worms to enter freely into the pile and aid the microorganisms.

With no pallets available, it is also possible to build one out of wooden beams by notching the ends, as in the construction of a "log" cabin (see picture 2).



Picture 2: Notching Wooden Beams Like Log Cabin

It is sometimes convenient to put several of these bins next to each other. It is usually convenient to leave one side unscrewed or unattached so that, when the compost is done, it is easier to shovel out (otherwise it would have to be lifted up out of the bin).

The collection method for human manure is somewhat different than for animal manure. The construction of a toilet over a bucket or bowl is necessary, and organic media should be placed in the bucket or bowl for sanitation so that the manure does not stick to the bucket or bowl as much or at all. We prefer a 5 gallon plastic bucket and wood chips or sawdust, the bucket because it is easy to clean and the wood chips because they are affordable and cut down on smells. The bucket is also easy to carry to the compost bin, and has a convenient lid for that transportation.

The composting toilet in the following picture consists of a platform to raise the seat to an appropriate height, a seat and seat cover for comfort, a 5 gallon plastic bucket and an access panel on the platform to more easily remove and insert the plastic bucket. Wood chips can easily be kept in a second bucket nearby. Toilet paper, urine and feces can all be composted together, the wood chips help the composting by ensuring that the compost does not get too acidic.



Keeping human manure at 25% of the organic matter is safe and advisable, though we highly recommend you undertake your own trials, and read Mr. Jenkin's book.

Secondary treatment by worms (vermaculture) I: about worms

Earthworms are not insects. They belong to the family Annelida Oligochaeta, which means "animals with ringed bodies and few bristles." There are many different species of earthworms, red wrigglers and night crawlers being two common species found in local gardens. Earthworms come in a wide range of sizes, and can be various colors such as red, pink, purple and brown. The largest earthworm yet discovered lives in Australia, and is on average 32 inches in length!

There are also many creatures that look like earthworms but are not earthworms at all. Roundworms, beetle larvae, caterpillars, and many other underground-dwelling creatures look like earthworms, but are in different families. So how can you tell the difference? Earthworms have rings around their bodies, and on each ring there are four tiny bristles. Since worms have no arms or legs, they use these bristles to grip, and in combination with muscle action to pull and push themselves along.

Earthworms have no eyes and ears, as these are unnecessary for their underground life. Instead, they have specialized skin that allows them to sense light and vibration directly from their brain, acting as eye and ear. That is all they need to find food and mates, and to avoid being eaten! They also have no skeleton; instead their bodies are filled with fluid to help them keep their shapes and to allow them more flexibility.

Earthworms have small mouths at one end of their bodies, which they use to grasp food they find on the surface of the earth and pull it down into their burrows. They are omnivores, meaning that they eat plant and animal matter, such as dead leaves, dead bugs, and larvae.

Depending on the species (and an individual worm's luck), they can live up to six years. During this time, they can each produce hundreds of baby worms. To help insure their species' survival, earthworms are hermaphrodites, meaning that each worm is both a mother and a father.

After mating, both worms lay eggs, which are buried deep underground for safety until the baby worms hatch.

You may have heard that if you cut a worm in two, both sides will live and become separate worms. This is most likely false: only the half of the cut worm with the brain in it may survive, if not too much of the rest of its body was cut off. This would be like you losing an arm or a leg; the lost arm or leg would not grow a new body, but the rest of you (the part with the head attached), would heal the wound and you would probably survive; any more lost than that and it would most likely prove fatal.

Worms do not eat roots, except by necessity: they prefer to forage for food on the surface. To digest hard-to-eat foods (such as raw plant leaves), they will cover the leaf with "saliva" and store them in burrows until they are edible.

Earthworms play an extremely important role in the garden. They eat organic matter and through digestion turn it into rich topsoil that is full of nutrients that plants use. They also help by digging burrows that aerate the soil, which allows plants' roots to dig down farther and easier. Charles Darwin spent many years studying the habits of worms and their effects on the environment. He summarizes many of the benefits worms provide to the gardener:

> *"They [worm burrows] allow the air to penetrate deeply into the ground. They also greatly facilitate the downward passage of roots of moderate size; and these will be nourished by the humus with which the burrows are lined. Many seeds owe their germination to having been covered by castings; and others buried to a considerable depth beneath accumulated castings lie dormant, until at some future time they are accidentally uncovered and germinate."*

Earthworms are also a good source of nutrition for many other garden-dwellers, such as birds, foxes, snakes, and frogs.

Secondary treatment by worms (vermaculture) II: worm farming

Compost may be fed to worms and they will turn the soil into "worm compost." This compost, amended by worm castings (worm mucus) is valuable as a soil amendment, as it is believed that the worm castings stabilize the soil and increase its ability to maintain proper moisture. However, these worm castings typically degrade fairly quickly, and the true value of the worm compost is questionable. Yet, the worms do encourage good microorganisms.

Some farmers will feed their worms scraps directly, allowing them to undertake most of the composting themselves. To do this, the vegetation (sometimes animal byproducts are composted as well) are placed directly on the surface of the worm bin's soil: the worms will rise to the surface to eat the scraps.

Worms also do well with paper scraps.

A bin is a box, sometimes with a door on the lower side to aid in the removal of finished worm compost. In the harvesting of the worm compost, the compost is passed through a screen so that the worms are not removed with the compost. This is necessary if the compost is to be sold: nobody wants to buy worms with the worm compost. However, sometimes worm compost is used on the farm itself: then, the time required to sift worms from their manure is not worth the expense. If the compost is to be used on the farm, train their worms to eat from one side of the bin by only

putting the food there. While some worms are lost when worm compost is taken from the side without the food, they will be happy enough in the garden.

In an anonymous article by the Louisiana Department of Environmental Quality *Making a Worm Farm*, the author describes the process very well. Though we disagree that red worms are necessary and dispute the claims against earthworms and night crawlers, it is on the whole much good information on their own, practical experience:

We use a sturdy plastic container that is about 7 inches deep, 9 inches wide and 14 inches long. The measurements are not real critical. This just happens to be an easy size for us to keep around the office and carry to presentations. If you are going to keep your worm farm inside, you will want it to be water tight. The worms are going to be happier when kept in the dark. (Kind of like some folks around here.) If your container is clear, wrap it with newsprint or place it in a cabinet or a opaque container to seal out the light. Make sure that the place you find to store the bin is away from vibrations. Worms will try to pack their bags and move to better digs if they are too near a source of vibration...

We really suggest that you use red worms. They are also called red wrigglers or manure worms. Do not use earthworms or night crawlers. They just are not cut out to do this job...

... Start with some shredded newspaper, moistened, not wet. Use the black and white pages. The classified ads are good, as are the stock market reports. Don't use the colored ad pages, it just makes the worms want to go shopping and you want them to stay in your box and convert the vegetable scraps. Add a couple of handfuls of garden soil, not potting soil, and a couple of crushed egg shells. Keep the bedding damp but not sopping. The moisture helps them to breathe, but too much water will drown them...

...You can feed your worms fruit and vegetable scraps and starchy scraps, like bread, oatmeal, and pasta. You can even feed them grits if they are southern worms, like ours. Do not feed them too much acidic foods, like citric fruits, coffee ground and tea bags. They do best with a pH between 7 & 8. You can use egg shells to balance the effects of coffee grounds, orange and lemon peels. Make sure that the eggshells are cooked before adding them to the worm farm. If they are not from boiled eggs, you can cook them by putting them in a cup of water in the microwave. Never feed your worms meat, poultry, dairy products, or salty food, like potato chips. These will create odors and attract insects. Your worms will eat about half their body weight each day. Take this into consideration when you are deciding how much food to add to the bin.

Worms require oxygen so keep the lid partially open to allow air to circulate. You should also turn the bedding with a trowel periodically to improve air circulation in the farm.

Worms will function very well at room temperature. Keep the farm temperature between +40 degrees F and +85 degrees F. Remember that heat will build up quickly in the farm if it is left in the sunlight.

Red worms reproduce often. Small, oval shaped cocoons in the bedding indicate that nature is taking its course. Cocoons may contain several baby worms and will take several weeks to hatch. Watch for tiny white worms. Poultry egg shells added to the bedding will provide calcium the worms need to reproduce. Don't worry about red worms taking over the estate, their population is limited by the size of their environment...

...Some folks sort the worms out of the castings and put the worms in fresh bedding. We have other things to do with our time and prefer a split harvest method. It helps if you have trained your worms ahead of time for this harvest method. To train your worms, you start feeding them at only one end of the bin. Do this for about a week. (Worms learn pretty fast.) Now take the bedding/castings out of the end of the farm where you were not feeding them and add it to your plants or garden. You will be removing about half to two thirds of the bedding/castings in this step. You will lose

some worms, but those were the ones that were not very smart. Remember you trained the others. Place the remaining bedding/castings in a container while you scrub the bin and fix new bedding. Prepare this bedding the same way you did the first time, damp newspaper, crushed egg shells, and a handful of dirt. Now add the worms you trained, castings and all onto the fresh bedding. Feed and you are back in business. I have found that the worms will move out of the old bedding in a couple of days. If you want a cleaner farm, you can remove the old bedding in a few days.

Sometimes the compost is sterilized afterward, but this removes much of the benefit of the worm composting.

The Louisiana article has presented the basics to a basically simple art: worms like it better when it is dark, but appreciate light when feeding and mating. The soil must be kept moist but not wet, and the soil should be turned regularly to ensure it is oxygenated very well: if not, you risk bad microorganisms killing your worms (though the worms will do their best to turn their own soil, turning the soil does not hurt them and does much to protect them).

Temperatures should be kept so that the worms are comfortable, and baby worms are always a good sign that the worms are happy.

Worms are also good for the in-soil composting described before. As tillage naturally composts debris in the soil, the worms aid the work, bringing debris down for their nests (or meal), stirring the soil, and finishing good compost into excellent compost.

If you want to learn more about worms, you can contact a local vermicomposter, or a person that harvests worms for composting, try making your own compost bin, or read Darwin's *The Formation of Vegetable Mould Through the Action of Worms*, or Norma Dixon's *Lowdown on Earthworms*.

Composting with mulches in no-till and tillage systems

Composting mulch is a mulch that actively composts. A mulch is a layer of organic matter placed on the soil to insulate it against weather and drought.

Use tree leaves and other organic material as a composting mulch overwinter. Place a layer of the debris on the surface of the beds and aisles. Over winter, the leaves and debris will keep the soil warmer, keep the microorganisms active and otherwise keep the field ready for very early spring work. The soil will not so readily freeze, and will be more fertile.

Because the farmer does not till under the beds until springtime (to maintain habitat for the wild creatures they rely on), the mulch helps to protect all those garden helpers. In the aisles, where the farmer does till, the mulch increases air space in the soil, and increases the insulative properties of the soil, keeping it warmer in the winter and cooler in the summer.

The farmer can never have too many leaves or debris for composting mulch. Grass clippings, old straw, branches, chipped wood, old vegetables... there is little that is inappropriate.

Some farmers raise a green manure to till into the soil for this purpose, but it is not a true composting mulch, as it is not a mulch: it is a crop in the ground. Nature provides an equivalent by how, in prairies, grasses bend over with the first snow to cover the ground and decay over the course of the following year, but by its limited contact with the ground, nature's mulch composts less well than human mulch, which fully contacts the ground, does.

Maple leaves are excellent composting mulch, because they are light, airy and, when tilled, create many air pockets. However, though maple leaves are our favorites, most tree leaves are very good.

No tillage until spring in beds allows plants to reseed: how to make a no-work garden

No tillage until spring allows plants to reseed in beds, encouraging biodiversity and beneficial weed growth, natural selection and breeding. Eventually, the farmer might, as Masanobu Fukuoka discovered, never need to plant again: a garden that reseeds itself and presents itself annually for the farmer's harvest is truly a no-work agriculture. To create this self-sustaining system, simply do not harvest your best plants, let them go to seed and either allow them to reseed themselves, or harrow the beds in the spring. The aisles then become permanent and do not move as in a standard system. We have tried this method with great success! It is especially advantageous to the famer who has little equipment and no labor to help with seeding.

Notes on succession and forest fires by the naturalist, Enos Mills (originally from "The Rocky Mountain Wonderland" chapter on Some Forest History, 1915)

The naturalist Enos Mills was fascinated by the phenomenon of succession, which to him was more visible after a fire than during the gradual deglaciation of our post-ice age era only because it was faster. –A.B. & M.C.

Two picturesque pine stumps stood for years in the edge of a grove near my cabin. They looked as old as the hills. Although they had wasted a little through weathering, they showed no sign of decay. Probably they were the ruins of yellow pine trees that before my day had perished in a forest fire. The heat of the fire that had caused their death had boiled the pores of these stumps full of pitch. They were thus preserved, and would endure a long, long time.

I often wondered how old they were. A chance to get this information came one morning when a number of old pines that grew around these stumps were blown over. Among those that went down were three large and ancient yellow pines and several smaller lodge-pole pines. These I dissected and studied, with the idea that their annual wood rings, together with the scars and embossments, might give information concerning the death of the old brown-gray stumps.

Two of the yellow pines showed two hundred and fifty-six annual rings; the other showed two hundred and fifty-five. All carried fire scars, received in the year 1781. Apparently, then, the stumps had been dead and weathering since 1781. The annual rings in the overthrown lodgepoles showed that they started to grow in 1782. Lodge-pole pines commonly spring up immediately after a fire; these had apparently taken possession of the ground as soon as it was laid bare by the fire that had killed and partly consumed the two yellow pines and injured the three scarred ones. Since the lodge-poles were free from fire scars, since the yellow pine showed no scar after 1781, and since all these trees had stood close about the stumps, it was plain that the stumps were the remnants of trees that perished in a forest fire in 1781.

Later, a number of trees elsewhere in the grove were called upon to testify, and these told a story that agreed with that of the trees that had stood close to the stumps. These stumps are now the newel-posts in a rustic stairway.

Near my home on the slope of Long's Peak are the records of an extraordinary succession of forest fires. During the last two hundred and fifty years eight large fires and numerous small ones have occurred. Each left a black, fire-engraved date-mark. The dates of some of these fires are 1675, 1707, 1753, 1781, 1842, 1864, 1878, 1885, and 1900. Each fire burned over from a few hundred to a few thousand acres. In part, nature promptly reforested after each fire; consequently some of the later

fires swept over areas that had been burned over by the earlier ones. Here and there a fire-scarred tree, escaping with its life, lived on to preserve in its rings the date of the conflagration. In one old pine I found seven widely separated scars that told of seven different fires. In addition to the records in isolated trees, there were records also in many injured trees in groves that had survived and in ragged forest-edges where forest fires had stopped. An excellent check on the evidence given by the annual rings of firescarred trees was found in the age of the new tree-growth that came up in the fire-swept territory in which, or on the borders of which, were the telltale fire-injured trees.

Some fires swept so clean that they left behind no date of their ravages, but here and there the character of the forest and of the soil in which it stood made me feel certain that the growth had arisen from the ashes of a fire, and that I could tell the extent of the fire. In most localities the fire-killed forest is at once restored by nature. That ever enthusiastic sower, the wind, reseeds most burned areas within a year. Burns on the Western mountains commonly are covered with young lodge-pole or aspen within three years. There are a few dry wind-swept slopes or places left rocky for which years or even centuries may be required to reearth and reforest.

Some members of the Pine Family endure fire much better than others. The 'big tree,' the redwood, and the yellow and sugar pines will survive far hotter fires than their relatives, for their vitals are protected by a thick sheath of slow-burning bark. The Western yellow pine is one of the best fire-fighters in the forest world. Its vitals appear able to endure unusual heat without death, and it will survive fires that kill neighboring trees of other kinds. In old trees the trunk and large limbs are thickly covered with heat-and-fire-resisting bark. In examining a number of these old fellows that were at last laid low by snow or landslide or the axe, I found that some had triumphantly survived a number of fiery ordeals and two or three lightning strokes. One pine of eight centuries carried the scars of four thunderbolts and seven wounds that were received from fires decades apart.

The deciduous, or broad-leaf, trees resist fires better than the coniferous, or evergreen, trees. Pines and spruces take fire much more readily than oaks and maples, because of the resinous sap that circulates through them; moreover, the pines and spruces when heated give off an inflammable gas which, rising in front of a forest fire, adds to the heat and destructiveness, and the eagerness of the blaze. Considered in relation to a fire, the coniferous forest is a poor risk because it is more inflammable than a deciduous one.

Another advantage possessed by broad-leaf trees lies in the rapid growth of their seedlings. Surface fires annihilate most tiny trees. Two-year-old chestnuts, maples, and, in fact, many of the broad-leaf youngsters, are three or more feet high, and are able to survive a severe fire; but two-year-old white pine, Engelmann spruce, or long-leaf pine are barely two inches high, — just fuzzy-topped matches stuck in the earth that perish in a flash from a single breath of flame.

The ability to send up sprouts, which most deciduous trees possess, is also a very great advantage in the fight against fire. A fire may destroy a deciduous forest and all its seeds without injuring the potent roots beneath the surface. The year following the fire, most of these roots send up sprouts that swiftly grow to replace the fallen forest. Among the so-called Pine Family, the ability to send up sprouts or shoots is limited to a few kinds, most prominent of which is the redwood.

Repeated forest fires have injured enormously the Southern hardwood forests; they have damaged millions of trees so that they have become hollow or punky-hearted. These fires have burned off limbs or burned into the trunks or the roots and made openings through which many kinds of fungi have entered the hearts of the trees, to doom them to rot and decay.

Forest fires have been common through the ages. Charcoal has been found in fossil. This has a possible age of a million years. Charred logs have been found, in Dakota and elsewhere, several

hundred feet beneath the surface. The big trees of California have fire scars that are two thousand years old.

The most remarkable forest fire records that I ever saw were found in a giant California redwood. This tree was felled a few years ago. Its trunk was cut to pieces and studied by scientific men, who from the number of its annual rings found the year of its birth, and also deciphered the dates of the various experiences the tree had had with fire.

This patriarch had stood three hundred feet high, was sound to the core, and had lived through two thousand one hundred and seventy-one years. Its existence began in the year 271 B.C. After more than five centuries of life, in A.D. 245 it was in the pathway of a forest fire from which it received a bad burn on the lower trunk. It was one hundred and five years before this burn was fully covered with tissue and bark.

Following this fire came the peaceful procession of twelve centuries. Eleven hundred and ninety-six times the golden poppies came to glorify the green hills of spring, while the songs of mating birds filled woods and meadows. More than a thousand times the aspens ripened and scattered their golden leaves, while this serene evergreen grew and towered more and more noble through the centuries.

Elsewhere the forests were dim with smoke, and on the Sierra during these centuries the heroic 'big trees' received many a scar from fire. But not until 1441 did fire again try this veteran. Soon after this burn was healed there came a third fire. This was less injurious than the preceding ones, for the wound that it inflicted healed in half a century.

Higher and more stately the tree grew, and in 1729 it attained the age of two thousand years. At the age of two thousand and eighty-eight years the fourth fire attacked it. This fire burned an eighteen-foot scar upon the trunk of the old tree. In 1900, after the lapse of almost a century, only a small part of this wound was overgrown. This year, 1900, came the reaper, the axeman, who laid low this aged and monumental tree!

What starts forest fires? Some are started by lightning; others are kindled by meteors that are flung from the sky, or by fire that is hurled or poured from a volcano; a few are caused by spontaneous combustion; and many are set by man. Down through the ages primitive and civilized men have frequently set fire to the forest. These fires are set sometimes accidentally, sometimes intentionally. The forest has been fired to drive out game, to improve pasturage, to bewilder the enemy during war, and to clear the land for the plow.

During one of my Colorado camping-trips a high October wind brought me the information that spruce wood was burning nearby. While I was searching for the fire in the thick needle carpet of the forest floor, a spark from above settled before me. A fire was sputtering and starting in a tree top about thirty feet above the earth. This fire was starting where a dead leaning tree-trunk was rasping and rubbing against an upright one. The bark of the standing tree was powdered and tufted with wood-dust which had been ground by friction from the trunks as they swayed and rotated in the wind. This inflammable wood-dust, together with accumulated bark-bits and needles, had been set on fire from the heat generated by these two big sticks rubbing together. Plainly this was a friction fire. The incessant swaying of treetops in the tireless wind occasionally causes a smoke from friction at points where overlapping limbs or entangled trees are rubbing. Within a few minutes after my discovery, this fire was roaring eagerly through the treetops.

Friction fires are rare, but my old notebooks tell of numerous fires that were set by lightning. Before this fire, which was in the Sangre de Cristo Mountains, had died out, a lightning-set fire in the mountains of central Colorado had attracted my attention with massive, magnificent smoke-clouds, which were two or three thousand feet above the mountain-tops. Though thirty miles

distant, these clouds occasionally took on the bossy white splendor of big cumuli assembling for summer rain. I resolved to see the fire at close range.

Until burned territory was reached, I followed along sky-line ridges through changing conditions of clear sky, smoke, and falling ashes, ready for swift retreat down a slope in case the fire advanced under smoke cover and surprised me. The burn was entered at the first edge I reached. Millions of seared and blackened trees were standing steadfastly where they had died at their post. All twigs and leafage were burned away, but the majority of the trees still carried their larger limbs and patches of bark. In places only the tree-trunk, a fire-carved totem pole, remained. Whirlwinds of flame had moved, and in places every burnable thing on the surface was consumed, and even tree-roots were burned out two and three feet beneath the surface.

Though weirdly interesting, these ashen fields of desolation were not wholly lifeless. Here, as elsewhere, feasters came to banquet, and good fortune brought favorites to the scene of panic and death. Flocks of gorged magpies were about, and unwontedly bold coyotes, both filled and foraging, were frequently met with. At one place a half-dozen beaver were portaging round a tumble of charred tree-trunks that obstructed the brook-channel. Fire had destroyed the food-supply, and the beaver were seeking home and harvest in other scenes. A grizzly bear was wading their pond and feasting on the dead trout that floated on the surface. Two black bears, despite terrible threats from the grizzly, claimed all the fish that came within reach of the shore. They discreetly kept out of the pond.

Two fawns and their mother lay dead at the foot of a cliff. Either blinded or terrorized by fire or smoke, they apparently had leaped 01 fallen to death. As I gained the top in climbing to investigate, an eagle swooped angrily at me from a topless trunk. Her mate with scorched feathers lay on the rocks nearby. On returning a few days later I found her still watching the lifeless one from the same perch in the dead tree.

In the heart of the burned tract was a thirty or-forty-acre tract of forest that had escaped the fire. It was surrounded with wide though broken barriers of rock ledges. In this green oasis were numerous wild-folk refugees. Chipmunks, rats, woodchucks, and birds were startlingly abundant, but no big game. Apparently the home people had welcomed the refugees, or had received them indifferently. The only fight noticed was between mountain rats. However, this crowding and overrunning of territory when the exciting fire was over, probably made many terrible pages of animal history, before exodus and death brought a normal readjustment of life to the territory.

Wandering on across the burn toward the fire-line, I came to the place where a ragged edged and beautiful glacier meadow had reposed, a poetic park among the spruces dark and tall. Commonly these meadows are sufficiently saturated to defy fire, but this one was burning, though slowly and with but little blaze or smoke. The fire was working toward the centre from the edges and eating downward from one to three feet. This kind of meadow usually carries a covering stratum of a kind of peat or turf which is composed almost entirely of matted grass or sedge roots that are almost free from earthy or mineral matter. These meadows lack warmth or soil sufficient to germinate tree seeds or to grow trees. Often they remain beautiful treeless gardens for generations, while wind and wash slowly bring sediment, or until a flood or landslip brings soil. The deep burning of the surface and the consequent deposit of ash on the new surface probably offered an abiding-place to the next adventurous tree seeds. Glacier meadows occasionally have this kind of ending.

Two prospectors were found at work in a spruce forest near which the fire started but which it did not reach for a week. These men said that, an hour or so after a thunder-shower of a few days before, one of the brown beetle killed pines had sent up a smoke-column. Apparently lightning had

struck this tree. The following day a small fire was burning near it. This expanded into the forest fire. Commonly it is a standing dead tree that is set on fire by the lightning, but the bolt sometimes fires accumulated trash around the roots where it enters the earth.

Within this extensive burn the trees had stood from thirty to one hundred and forty feet high and from two hundred to three thousand to the acre, and they were from thirty to four hundred and fifty years old. A majority were about two centuries old. The predominating kinds were yellow pine, Douglas spruce, Engelmann spruce, and aspen. Different altitudes, forest fires, and a variety of slope-exposures, along with the peculiar characteristics of each species, had distributed these in almost pure stands, an area of each kind to itself. There was some overlapping and mixing, but lodge-pole pine noticeably stood by itself.

Where first encountered, this fire was roaring through a thick second growth of lodge-pole pine. Scattered through this young growth were hundreds of dead and limbless trees killed by a fire of thirty years before. The preservative effect of their fiery death had kept these great pillars sound, though they had become checked and weathered. They burned slowly, and that night while the fire-front was storming a ridge, these columns spread sparks and flames from split sides, or as gigantic candles blazed only at the top. Yellow pines and Douglas spruces killed in an intensely hot fire are so cooked and preserved that they will resist weathering or rot for decades. I have seen a few of these pitchy broken fellows standing erect in the depth of a century -old second generation of forest with the arms of the living trees about and above them.

Down a slope a fire moves more slowly and with lower temperature than upward on the same slope. A fire may rush in a minute up a slope which it would require a day to creep down. A fire is more all-consuming in going up, and even after years have passed, the remains left on a slope will often enable one to determine whether a fire swept up or crept down. One peculiarity of flames in young growths on steep slopes is that they sometimes dart up the heights in tongues, leaving narrow ragged stretches of unburned trees! Usually these fiery tongues sweep in a straight line up the slope.

The intense heat of a passing fire-front is withering at long distances. I have known a fire to blister aspen clumps that were seven or eight hundred feet from the nearest burned trees. The passing flames may have been pushed much closer than this by slow heavy air-swells or by the brief blasts of wild wind rushes.

The habits of forest fires are largely determined by slope-inclination, wind-speed, and the quantity and quality of the fuel. In places the fire slips quietly along with low whispering, then suddenly it goes leaping, whirling, and roaring. A fire may travel less than one mile or farther than one hundred miles in a day. The ever varying slope and forest conditions in the mountains are constantly changing the speed and the enthusiasm of a fire. Where all conditions are favorable, it sweeps level stretches at a mile-a-minute speed and rolls up slopes with the speed of sound!

One evening I climbed a high ridge that stood about half a mile in front of a heavily forested peninsula which the fire-front would reach in a few hours. The fire was advancing across the valley with a front of about two miles. On arriving at the top of the ridge, I came up behind a grizzly bear seated on his haunches like a dog, intently watching the fire below. On discovering me he took a second look before concentrating his mind on a speedy retreat. Along the ridge about a quarter of a mile distant, a number of mountain sheep could be seen through the falling ashes, with heads toward the fire, but whether they were excited or simply curious could not be determined.

The forested peninsula which extended from between two forested canons had a number of meadow openings on the slopes closest to me. Around these were many brilliant fiery displays. Overheated trees in or across these openings often became enveloped in robes of invisible gas far in advance of the flames. This gas flashed and flared up before the tree blazed, and occasionally it

convoyed the flames across openings one hundred feet or so above the earth. Heated isolated trees usually went with a gushing flash. At other places this flaming sometimes lasted several seconds, and, when seen through steamy curtains or clouds of smoke, appeared like geysers of red fire.

At times there were vast scrolls and whirling spirals of sparks above and around the torrential, upstreaming flames of the fire-front. Millions of these sparks were sometimes formed by high outflowing air streams into splendid and far-reaching milky way's. In moments of general calm the sky was deeply filled with myriads of excited sparks, which gradually quieted, then floated beautifully, peacefully up to vanish in the night.

Meantime the fire-front was pushed by wind currents and led by ridges. By the time the fire-line had advanced to the steeper slopes it was one vast U about three miles long. Its closed end was around the peninsula toward me. The fire-front rushed upward through the dense forest of the peninsula steeps more swiftly than the wildest avalanche could have plunged down. The flames swept across three-hundred-foot grassy openings as easily as breakers roll in across a beach. Up the final two thousand feet there were magnificent outbursts and sheets of flame with accompanying gale and stormy ocean roars. Terrific were the rushes of whirled smoke-and-flame clouds of brown, ashen green, and sooty black. There were lurid and volcanic effects in molten red and black, while tattered yellow flames rushed, rolled, and tumbled everywhere.

An uprushing, explosive burst of flames from all sides wrapped and united on the summit. For a minute a storm of smoke and flame filled the heavens with riot. The wild, irresistible, cyclonic rush of fiery wind carried scores of treelimbs and many blazing treetops hundreds of feet above the summit. Fire and sparks were hurled explosively outward, and a number of blazing treetops rushed off in gale-currents. One of these blazing tops dropped, a destructive torch, in a forest more than a mile distant from the summit!

Notes on succession and forest fires by the naturalist, Enos Mills (originally from "The Rocky Mountain Wonderland" chapter on Bringing Back the Forest, 1915): Part II

Here Mills explores the nature of pioneer species and individuals, and the factors that both check their advance and encourage their expansion. –A.B. & M.C.

During the last fifty years repeated fires have swept through Western forests and destroyed vast quantities of timber. As a result of these fires, most species of trees in the West have lost large areas of their territory. There is one species of tree, however, that has, by the very means of these fires, enormously extended its holdings and gained much of the area lost by the others. This species is the lodge-pole pine.

My introduction to this intrepid tree took place in the mountains of Colorado. One day, while watching a forest fire, I paused in the midst of the new desolation to watch the behavior of the flames. Only a few hours before, the fire had stripped and killed the half-blackened trees around me. All the twigs were burned off the tree beneath which I stood, but the larger limbs remained; and to each of these a score or more of blackened cones stuck closely. Knowing but little of trees and being interested in the fire, I paid no attention to these cones until a number of thin, brownish bits, like insects' wings, came fluttering and eddying easily down from the treetop.

The ashes and the earth around me were still warm, and the air was misty with smoke. Nearby, a tall snag and some fallen logs smoked and blazed by turns. Again, a number of these tissue bits came fluttering and whirling lightly down out of the fire-killed treetop. Watching carefully, I

saw brown tissue bits, one after another, silently climb out of a blackened cone and make a merry one-winged flight for the earth. An examination of these brown bits showed that they were the fertile seeds of the lodge-pole pine. With heroic and inspiring pioneer spirit, this indomitable tree was sowing seeds, beginning the work of reconstruction while its fire-ruined empire still smoked.

It is the first tree to be up and doing after destructive flames sweep by. Hoarded seeds by the million are often set free by fire, and most of these reach the earth within a few hours or a few days after the fiery whirlwind has passed by. Being winged and exceedingly light, thousands are sometimes blown for miles. It would thus appear that the millions of lodge-pole seeds released by fire begin under most favorable conditions. Falling as they do, upon earth cleaned for their reception, there is little or no competition and but few enemies. The fire has banished most of the injurious animals, consumed competitors and their seeds, and prepared an ashen, mineralized seed-bed; not a leaf shades it, and altogether it is an ideal place for the lodge-pole seed and seedlings.

It seems extraordinary that fire, the archenemy of the lodge-pole pine, should so largely contribute to the forest extension of this tree. It is not only one of the most inflammable of trees but it is easily killed by fire. Despite these weaknesses, such are the remarkable characteristics of this species that an increase in the number of forest fires in the West will enable this tree to extend its holdings; on the other hand, a complete cessation of fires would, in time, almost eliminate it from the forest!

The lodge-pole pine (Pinus contorta, var. Murrayana) lives an adventurous frontier life, and of the six hundred kinds of North American trees no other has so many pioneer characteristics. This species strikingly exhibits some of the necessary requisites in trees that extend or maintain the forest-frontier. The characteristics which so largely contribute to its success and enable it to succeed through the agency of fire are its seed-hoarding habit and the ability of its seedling to thrive best in recently fire cleaned earth, in the full glare of the sun. Most coniferous seedlings cannot stand full sunlight, but must have either completely or partly shaded places for the first few years of their lives.

Trees grow from seed, sprouts, or cuttings. Hence, in order to grow or to bring back a forest, it is necessary to get seeds, sprouts, or cuttings upon the ground. The pitch pine of New Jersey and the redwood of California, whether felled by fire or by axe, will sprout from root or stump. So, too, will the aspen, chestnut, cherry, cottonwood, elm, most of the oaks, and many other kinds of trees. The extensive areas in New Brunswick and Maine that were cleared by the fires of 1825 were in large part at once regrown with aspen, most of which sprouted from the roots of burned aspens. Willow is easily propagated from a short section of the root, trunk, or limb. These sections may be broken from the tree by accident, be carried miles downstream, lodge on shore or shoal, and there take root and grow. Beaver dams made of willow poles are commonly overgrown in a short time with willow. Several years ago a tornado wrecked hundreds of willows along a Kansas stream. Each willow was broken into scores of pieces, which were carried and dropped along the track of the tornado. Countless numbers of them were stuck into the earth. Several thousand willow trees were thus successfully planted by this violent wind.

Seeds are the chief means by which the forest is extended or produced. They are sown by wind and gravity, by water, by birds and beasts. I have dwelt at length upon the romance of seed scattering in "The Spell of the Rockies," in the chapter concerning "The Fate of a Tree Seed." Each species of tree has its own way of scattering its seeds. Once upon the earth, they and the seedlings that may spring from them have peculiar limitations and special advantages. In some cases — as, for instance, with most willows and poplars — these seeds must in an extremely short time find a place and germinate or they perish; the seeds of few trees will stand exposure for two years and still be fertile.

It is only a question of a few years until seeds are carried to every treeless locality. They may journey down-stream or across lakes on a log, fly with birds across mountain-ranges, ride by easy stages clinging to the fur of animals, or be blown in storms across deserts; but these adventurous seeds may find grass in possession of the locality and so thickly sodded that for a century or longer they may try in vain to establish a forest.

Commonly wind-blown seeds are first upon the ground and the most numerous. Though it is of advantage to be the first upon the ground, it is of immense importance that the seed which

Bringing falls in an opening produce a seedling which thrives in the sun-glare, — which grows without shade. The seedlings of our great oaks and most strong and long-lived trees cannot thrive unless shielded from the sun, sheltered from the wind, and protected from the sudden temperature changes which so often afflict openings. While these maintain the forest areas, they extend it but little. Only a small number of trees have the peculiar frontier characteristics. Young trees which cannot live in the sun are called tolerant, — they tolerate shade and need it. Species which conquer sunny territory are called intolerant, — they cannot stand shade and need sunlight. It will thus be seen that the acquirement of treeless territory by any species of tree demands not only that the tree get its seeds upon the earth in that territory, but also that the seeds, once there, have the ability to survive in the sunlight and endure the sudden changes of the shelterless opening. Most species of oaks, elms, firs, and spruces require shade during their first few years, and though they steadfastly defend possessions, they can do but little toward winning new territory. On the other hand, aspens, willows, gray birch, cottonwood, old-field pine, and lodge-pole pine produce seedlings that glory in the sunlight and seek to gain more territory, — to push forward the forest-frontier.

Again and again the forest has been swept away by fire; but again and again a few aggressive species have retaken speedily the lost territory. In this pioneer reclamation the aspen and the lodge-pole are leaders. The aspen follows the water-courses, running along the muddy places, while the lodge-pole occupies the dry and rocky slope of the burned area. Seen from a distance the aspen groves suggest bright ribbons and pockets on the somber cloak with which lodge-pole drapes the mountain. And even beneath the trees the contrast between the methods of these two agents of reforestation is marked. The lodge-pole pine is all for business. Its forest floor is swept clean and remains uncarpeted. The aspen groves, on the other hand, seem like the haunts of little women. Here the floor has a carpet of grass gay with columbines, sweet peas, and wild roses. While the aspens and the lodge-poles are still young they begin to shelter the less hardy coniferous seedlings. But sooner or later both the aspens and the lodge-poles themselves are smothered by their nurslings. They then surrender their areas to forest trees that will live to be many times their age.

But that species which is preeminently successful in bringing back the forest to a burned over area is the lodge-pole pine. It produces seeds each year and commonly hoards them for many years. Its seeds are light, winged, and easily carried by the wind. As they are frequently released by fire, they are sown at the most opportune time, scattered in profusion, and, in windy weather, transported long distances.

Commonly lodge-pole pine holds on to, or hoards, a percentage of the seeds it bears; that is to say, these seeds remain in the cone, and the cone remains on the tree. In some situations it begins to bear at eight years of age, and in most localities by the time it is twelve. Year after year the cones, with their fertile seeds safely enclosed, are borne and cling to the tree. Some of these cones remain unopened from three to nine years. A small percentage of them do not open and distribute their seeds until they have been on the tree from twelve to twenty years, and many of the cones cling to the tree through life.

Under favorable conditions the lodge-pole is a rapidly growing conifer. In a forty-five-year growth near my home, the varied light and soil conditions were so spotted that in a small area marked differences in growth were shown. A few clusters were vigorous, and the trees showed an average diameter of six inches and a height of thirty-four feet. From this the size dropped, and in one group the individuals were less than one inch in diameter and scarcely tall enough to be used as a cane; yet all were forty-five years old.

The lodge-pole is not long-lived. The oldest one I ever measured grew upon the slope of Long's Peak. It was three hundred and forty-six years of age, measured twenty-nine inches in diameter, and stood eighty-four feet high. A study of its annual rings showed that at the age of two hundred it was only eleven inches in diameter, with a height of sixty-nine feet. Evidently it had lived two centuries in an overcrowded district. The soil and moisture conditions were good, and apparently in its two hundred and second year a forest fire brought it advantages by sweeping away its crowding, retarding competitors. Its annual ring two hundred and two bore a big fire-scar, and after this age it grew with a marked increase of rapidity over the rate of previous years. A mature lodge-pole of average size and age measures about eighteen inches in diameter and stands sixty feet high, with an age of between one hundred and twenty-five and one hundred and seventy-five years.

The clinging habit of the cones of the lodge-pole pine in rare cases causes numbers of them to be caught by the expanding tissues, held, and finally overgrown and completely buried up in the tree like a knot. Commonly the first crop of cones is the one caught. These are usually stuck a few inches apart in two vertical opposite rows along the slender trunk. Each knob-like cone is held closely against the trunk by a short, strong stem.



Overgrown cones in the heart of a lodge-pole pine, showing also the cones as borne on the twigs and an early stage of the overgrowing process)

I have a ten-foot plank from the heart of a large tree which shows twenty-eight imbedded cones. The biography of this tree, which its scroll of annual rings pictured in the abstract, is of interest. The imbedded cones grew upon the sapling before it was thirty years old and when it was less than twenty-five feet high. They appeared upon the slender trunk before it was an inch in diameter. Twenty-six annual wood-rings formed around them and covered them from sight as completely as the seeds the cone-scales clasped and concealed. The year of this completed covering, as the annual rings showed, was 1790. Then the tree was sixty-six years of age; it came into existence in 1724, and apparently, from the forest-history of the place, in the pathway of a fire. This lodge-pole lived on through one hundred and eighty-two years. In the spring of 1906 a woodsman cut it down. A few weeks later two-inch planks were sliced from the log of this tree in a sawmill. The fourth cut split the pith of the tree, and the startled sawyer beheld a number of imbedded cones stuck along and around the pith, the heart of this aged pine. These cones and the numerous seeds which they contained were approximately one hundred and fifty years old. I planted two dozen of the seeds, and three of these were fertile and sprouted.

Old trees may carry hundreds or even thousands of seed-filled cones. Once I counted 14,137 of these on the arms of one veteran lodge-pole. If we allow but twenty seeds to the cone, this tree alone held a good seed-reserve. Commonly a forest fire does not consume the tree it kills. With a lodge-pole it usually burns off the twigs and the foliage, leaving many of the cones unconsumed. The cones are excellent fire resisters, and their seeds usually escape injury, even though the cones be charred. The heat, however, melts the resinous sealing-wax that holds the cone-scales closed. I have known the heat of a forest fire to be so intense as to break the seals on cones that were more than one hundred feet beyond the side line of the fire.

In most cases the seedlings spring up on a burned-over area the year following the fire. Often they stand as thickly as grain in the field. Under favorable conditions as many as one hundred and fifty thousand will appear upon an acre, and a stand of fifty thousand to the acre is not uncommon. Starting in a close, even growth, they usually suppress for years all other species of trees and most other plants. Their growth is mostly upward — about the only direction possible for expansion — with moderate rapidity. In a few years they are tall but exceedingly slender, and they become poles in from twenty-five to fifty years. The trappers named this tree lodge-pole because of its common use by the Indians for lodge, or tepee, poles.

In overcrowded stands, especially those in which groups or individual trees have slight advantages over their neighbors, a heavy percentage of the growth may die annually for the want of nutrition. If equal opportunities prevail in a crowded tract, all will grow slowly until some have an advantage; these will then grow more rapidly, and shade and suppress neighboring competitors.

The lodge-pole does good work in developing places that are inhospitable to other and longer-lived trees, but it gives way after preparing for the coming and the triumph of other species. By the time lodge-poles are sixty years of age their self-thinning has made openings in their crowded ranks. In these openings the shade enduring seedlings of other species make a start. Years go by, and these seedlings become great trees that overtop the circle of lodge-poles around them. From this time forward the lodge-pole is suppressed, and ultimately its fire-acquired territory is completely surrendered to other species. It holds fire-gained areas from seventy-five to one hundred and fifty years. It is often supplanted by Douglas or Engelmann spruce. Let fire sweep these, and back comes the lodge-pole pine.

Though it distances all competitors in taking possession of fire-cleared territory, it is less successful than its fellows in entering a territory already occupied by other trees or by grass, because its seedlings cannot endure shade, and its seeds will not germinate or take root except they be

brought directly into contact with clean mineral soil. The lodge-pole, therefore, needs the assistance of fire both to acquire and to hold territory. Increase the number of forest fires, and the lodge-pole extends its holdings; if we could stop fires altogether, the lodge-pole would become almost extinct.

The lodge-pole has an astonishing altitudinal as well as latitudinal range. Scattered pretty well over the mountain region of the western United States, thence northward along the coast over much of the head-waters of the Yukon in Alaska, it occupies an enormous area. Over this it adapts itself with marked success to a variety of soil, moisture, and climatic conditions, and covers ragged tracts from warm sea-beaches to dry, cold mountain slopes eleven thousand feet above the sea. In many places it surrenders the traditional pole form of its race and wins success by becoming thick-barked, stocky, and limb-covered from top to bottom.

Reading tree rings – a lesson from John Muir, as taught by Enos Mills (from "The Story of a Thousand Year Old Pine," 1914)

In contrast to the casual observations of succession, Enos Mills now teaches the deliberate observation of a tree.

The art of reading tree rings to understand local history has been improved greatly since Jethro Tull's 18th Century and Enos Mill's 19th and 20th Centuries: now, sophisticated algorithms can compute atmospheric composition, temperature, rainfall and other important data from chemical and visual analysis of the rings: trees respond to their environments in very predictable ways! Those who would understand an ecology must learn to read the histories kept by the trees, the oldest living creatures present on the land.

It is not necessary to slay the trees to gain their memories: a core sample is easily obtained and pitched over to prevent any infection to the tree. However, every opportunity should be taken, and if a tree is to be felled, or naturally falls, observe its rings and learn.

We would add, too, to observe the way trees grow around inanimate objects. Some human relics can last hundreds or thousands of years – tree age – and if a water trough is surrounded by a grove of oaks, it is likely that the land is an abandoned pasture. Observe how the trees grow: are there many tightly together, as if they had been cut and are regrowing? Are they spaced well apart, as if hundreds or thousands of years have allowed them to properly distance themselves? Observe the erosion on the land: if soil is now held by roots where extensive erosion occurred, some indication may be gained that the vegetation was not always there.

The histories of trees are more accurate than those of people: people lie, or confuse themselves, but trees never do. An orchard can be found to be long past its prime, the abuses or benevolence of its former farmers revealed in the memories of trees. But domestic trees are not the only ones that remember: exploring the eastern plains of Colorado, we have discovered ancient stumps from ancient forests: the human written histories and tree histories agreed that the forests had been cut to build mighty cities and for fuel. However, discussion with residents – none of whom had themselves or their families lived in the area before the lumbering – would say otherwise: they would report that the land had always been treeless. And, to their short memories the land had always been treeless.

But the trees remembered, as did the newspaper archives. And, after the newspaper archives will fall to dust, the trees and land will remember still. And the land will still be kindly to those who would replace the trees, granting to them bountiful harvests of valuable fruits and nuts and lumber; the land will be kindly to those who replace the bushes and other vegetation, who welcome back the numerous animals and place, in eternal reservation, wilderness for the sake of nature's beauty. –A.B. & M.C.

The peculiar charm and fascination that trees exert over many people I had always felt from childhood, but it was that great nature-lover, John Muir, who first showed me how and where to learn their language. Few trees, however, ever held for me such an attraction as did a gigantic and venerable yellow pine which I discovered one autumn day several years ago while exploring the southern Rockies. It grew within sight of the Cliff-Dwellers' Mesa Verde, which stands at the corner of four States, and as I came upon it one evening just as the sun was setting over that mysterious tableland, its character and heroic proportions made an impression upon me that I shall never forget, and which familiar acquaintance only served to deepen while it yet lived and before the axeman came. Many a time I returned to build my camp-fire by it and have a day or a night in its solitary and noble company. I learned afterwards that it had been given the name "Old Pine," and it certainly had an impressiveness quite compatible with the age and dignity which go with a thousand years of life.

When, one day, the sawmill-man at Mancos wrote, "Come, we are about to log your old pine," I started at once, regretting that a thing which seemed to me so human, as well as so noble, must be killed.

I went with the axemen who were to cut the old pine down. A grand and impressive tree he was. Never have I seen so much individuality, so much character, in a tree. Although lightning had given him a bald crown, he was still a healthy giant, and was waving evergreen banners more than one hundred and fifteen feet above the earth. His massive trunk, eight feet in diameter at the level of my breast, was covered with a thick, rough, golden-brown bark which was broken into irregular plates. Several of his arms were bent and broken. Altogether, he presented a timeworn but heroic appearance.

It is almost a marvel that trees should live to become the oldest of living things. Fastened in one place, their struggle is incessant and severe. From the moment a baby tree is born — from the instant it casts its tiny shadow upon the ground — until death, it is in danger from insects and animals. It cannot move to avoid danger. It cannot run away to escape enemies. Fixed in one spot, almost helpless, it must endure flood and drought, fire and storm, insects and earthquakes, or die.

Trees, like people, struggle for existence, and an aged tree, like an aged person, has not only a striking appearance, but an interesting biography. I have read the autobiographies of many century-old trees, and have found their life-stories strange and impressive. The yearly growth, or annual ring of wood with which trees envelop themselves, is embossed with so many of their experiences that this annual ring of growth literally forms an autobiographic diary of the tree's life.

I wanted to read Old Pine's autobiography. A veteran pine that had stood on the southern Rockies and struggled and triumphed through the changing seasons of hundreds of years must contain a rare life-story. From his stand between the Mesa and the pine-plumed mountain, he had seen the panorama of the seasons and many a strange pageant; he had beheld what scenes of animal and human strife, what storms and convulsions of nature! Many a wondrous secret he had locked within his tree soul. Yet, although he had not recorded what he had seen, I knew that he had kept a fairly accurate diary of his own personal experience. This I knew the saw would reveal, and this I had determined to see.

Nature matures a million conifer seeds for each one she chooses for growth, so we can only speculate as to the selection of the seed from which sprung this storied pine. It may be that the cone in which it matured was crushed into the earth by the hoof of a passing deer. It may have been hidden by a jay; or, as is more likely, the tree may have grown from one of the uneaten cones which a squirrel had buried for winter food. Fremont squirrels are the principal nurserymen for all the Western pineries. Each autumn they harvest a heavy percentage of the cone crop and bury it for winter. The seeds in the uneaten cones germinate, and each year countless thousands of conifers

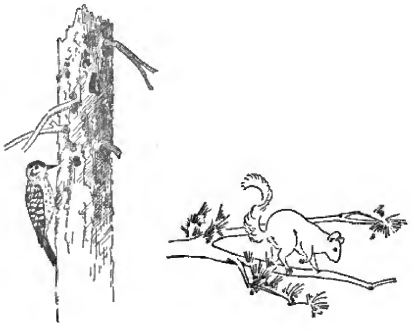
grow from the seeds planted by these squirrels. It may be that the seed from which Old Pine burst had been planted by an ancient ancestor of the protesting Fremont squirrel whom we found that day in apparent possession of the premises; or this seed may have been in a cone which simply bounded or blew into a hole, where the seed found sufficient mould and moisture to give it a start in life.

Two loggers swung their axes: at the first blow a Fremont squirrel came out of a hole at the base of a dead limb near the top of the tree and made an aggressive claim of ownership, setting up a vociferous protest against the cutting. As his voice was unheeded, he came scolding down the tree, jumped off one of the lower limbs, and took refuge in a young pine that stood nearby. From time to time he came out on the top of the limb nearest to us, and, with a wry face, fierce whiskers, and violent gestures, directed a torrent of abuse at the axemen who were delivering death-blows to Old Pine.

The old pine's enormous weight caused him to fall heavily, and he came to earth with tremendous force and struck on an elbow of one of his stocky arms. The force of the fall not only broke the trunk in two, but badly shattered it. The damage to the log was so general that the sawmill-man said it would not pay to saw it into lumber and that it could rot on the spot.

I had come a long distance for the express purpose of deciphering Old Pine's diary as the scroll of his life should be laid open in the sawmill. The abandonment of the shattered form compelled the adoption of another way of getting at his story. Receiving permission to do as I pleased with his remains, I at once began to cut and split both the trunk and the limbs, and to transcribe their strange records. Day after day I worked. I dug up the roots and thoroughly dissected them, and with the aid of a magnifier I studied the trunk, the roots, and the limbs.

I carefully examined the base of his stump, and in it I found ten hundred and forty-seven rings of growth! He had lived through a thousand and forty-seven memorable years. As he was cut down in 1903, his birth probably occurred in 856.



In looking over the rings of growth, I found that a few of them were much thicker than the others; and these thick rings, or coats of wood, tell of favorable seasons. There were also a few extremely thin rings of growth. In places two and even three of these were together. These were the results of unfavorable seasons, — of drought or cold. The rings of trees also show healed wounds, and tell of burns, bites, and bruises, of torn bark and broken arms. Old Pine not only received injuries in his early years, but from time to time throughout his life. The somewhat kinked condition of several of the rings of growth, beginning with the twentieth, shows that at the age of twenty he sustained an injury which resulted in a severe curvature of the spine, and that for some years he was somewhat stooped. I was unable to make out from his diary whether this injury was the result of a tree or some object falling upon him and pinning him down, or whether his back had been overweighted and bent by wet, clinging snow. As I could find no scars or bruises, I think that snow must have been the cause of the injury. However, after a few years he straightened up with youthful vitality and seemed to outgrow and forget the experience.

A century of tranquil life followed, and during these years the rapid growth tells of good seasons as well as good soil. This rapid growth also shows that there could not have been any crowding neighbors to share the sun and the soil. The tree had grown evenly in all quarters, and the pith of the tree was in the center. But had one tree grown close, on that quarter the old pine would have grown slower than on the others and have been thinner, and the pith would thus have been away from the tree's center.

When the old pine was just completing his one hundred and thirty-fifth ring of growth, he met with an accident which I can account for only by assuming that a large tree that grew several yards away blew over, and in falling, stabbed him in the side with two dead limbs. His bark was broken and torn, but this healed in due time.

Short sections of the dead limbs broke off, however, and were embedded in the old pine. Twelve years' growth covered them, and they remained hidden from view until my splitting revealed them. Two other wounds started promptly to heal and, with one exception, did so.

A year or two later some ants and borers began excavating their deadly winding ways in the old pine. They probably started to work in one of the places injured by the falling tree. They must have had some advantage, or else something must have happened to the nuthatches and chickadees that year, for, despite the vigilance of these birds, both the borers and the ants succeeded in establishing colonies that threatened injury and possibly death.

Fortunately relief came. One day the chief surgeon of all the Southwestern pineries came along. This surgeon was the Texas woodpecker. He probably did not long explore the ridges and little furrows of the bark before he discovered the wound or heard these hidden insects working. After a brief examination, holding his ear to the bark for a moment to get the location of the tree's deadly foe beneath, he was ready to act. He made two successful operations. Not only did these require him to cut deeply into the old pine and take out the borers, but he may also have had to come back from time to time to dress the wounds by devouring the ant-colonies which may have persisted in taking possession of them. The wounds finally healed, and only the splitting of the affected parts revealed these records, all filled with pitch and preserved for nearly nine hundred years.

Following this, an even tenor marked his life for nearly three centuries. This quiet existence came to an end in the summer of 1301, when a stroke of lightning tore a limb out of his round top and badly shattered a shoulder. He had barely recovered from this injury when a violent wind tore off several of his arms. During the summer of 1348 he lost two of his largest arms. These were sound, and more than a foot in diameter at the points of breakage. As these were broken by a down-pressing weight or force, we may attribute the breaks to accumulations of snow.

The oldest, largest portion of a tree is the short section immediately above the ground, and, as this lower section is the most exposed to accidents or to injuries from enemies, it generally bears evidence of having suffered the most. Within its scroll are usually found the most extensive and interesting autobiographical impressions.

It is doubtful if there is any portion of the earth upon which there are so many deadly struggles as upon the earth around the trunk of a tree. Upon this small arena there are battles fierce and wild; here nature is 'red in tooth and claw.' When a tree is small and tender, countless insects come to feed upon it. Birds come to it to devour these insects. Around the tree are daily almost merciless fights for existence. These death-struggles occur not only in the daytime, but in the night. Mice, rats, and rabbits destroy millions of young trees. These bold animals often flay baby trees in the daylight, and while at their deadly feast many a time have they been surprised by hawks, and then they are at a banquet where they themselves are eaten. The owl, the faithful night watchman of trees, often swoops down at night, and as a result some little tree is splashed with the blood of the very animal that came to feed upon it. The lower section of Old Pine's trunk contained records which I found interesting. One of these in particular aroused my imagination. I was sawing off a section of this lower portion when the saw, with a buzz-z-z-z, suddenly jumped. The object struck was harder than the saw. I wondered what it could be, and, cutting the wood carefully away, laid bare a flint arrowhead. Close to this one I found another, and then with care I counted the rings of growth to find out the year that these had wounded Old Pine. The outer ring which these arrowheads had pierced was the six hundred and thirtieth, so that the year of this occurrence was 1486.

Had an Indian bent his bow and shot at a bear that had stood at bay backed up against this tree? Or was there around this tree a battle among Indian tribes? Is it possible that at this place some Cliff-Dweller scouts encountered their advancing foe from the north and opened hostilities? It may be that around Old Pine was fought the battle that is said to have decided the fate of that mysterious race, the Cliff-Dwellers. The imagination insists on speculating with these two arrowheads, though they form a fascinating clue that leads us to no definite conclusion. But the fact remains that Old Pine was wounded by two Indian arrowheads some time during his six hundred and thirtieth summer.

The year that Columbus discovered America, Old Pine was a handsome giant with a round heart held more than one hundred feet above the earth. He was six hundred and thirty-six years old, and with the coming of the Spanish adventurers his lower trunk was given new events to record. The year 1540 was a particularly memorable one for him. This year brought the first horses and bearded men into the drama which was played around him. This year, for the first time, he felt the edge of steel and the tortures of fire. The old chronicles say that the Spanish explorers found the cliff-houses in the year 1540. I believe that during this year a Spanish exploring party may have camped beneath Old Pine and built a fire against his instep, and that some of the explorers hacked him with an axe. The old pine had distinct records of axe and fire markings during the year 1540. It was not common for the Indians of the West to burn or mutilate trees, and it was common for the Spaniards to do so, and as these hackings in the tree seemed to have been made with some edged tool sharper than any possessed by the Indians, it at least seems probable that they were made by the Spaniards. At any rate, from the year 1540 until the day of his death, Old Pine carried these scars on his instep.

As the average yearly growth of the old pine was about the same as in trees similarly situated at the present time, I suppose that climatic conditions in his early days must have been similar to the climatic conditions of to-day. His records indicate periods of even tenor of climate, a year of

extremely poor conditions, occasionally a year crowned with a bountiful wood harvest. From 1540 to 1762 I found little of special interest. In 1762, however, the season was not regular. After the ring was well started, something, perhaps a cold wave, for a time checked his growth, and as a result the wood for that one year resembled two years' growth; yet the difference between this double or false ring and a regular one was easily detected. Old Pine's 'hard times' experience seems to have been during the years 1804 and 1805. I think it probable that those were years of drought. During 1804 the layer of wood was the thinnest in his life, and for 1805 the only wood I could find was a layer which only partly covered the trunk of the tree, and this was exceedingly thin.

From time to time in the old pine's record, I came across what seemed to be indications of an earthquake shock; but late in 1811 or early in 1812, I think there is no doubt that he experienced a violent shock, for he made extensive records of it. This earthquake occurred after the sap had ceased to flow in 1811, and before it began to flow in the spring of 1812. In places the wood was checked and shattered. At one point, some distance from the ground, there was a bad horizontal break. Two big roots were broken in two, and that quarter of the tree which faced the cliffs had suffered from a rock bombardment. I suppose the violence of the quake displaced many rocks, and some of these, as they came bounding down the mountain-side, collided with Old Pine. One, of about five pounds' weight, struck him so violently in the side that it remained embedded there. After some years the wound was healed over, but this fragment remained in the tree until I released it.

During 1859 someone made an axe mark on the old pine that may have been intended for a trail-blaze, and during the same year another fire badly burned and scarred his ankle. I wonder if some prospectors came this way in 1859 and made camp by him.

Another record of man's visits to the tree was made in the summer of 1881, when I think a hunting or outing party may have camped near here and amused themselves by shooting at a mark on Old Pine's ankle. Several modern rifle-bullets were found embedded in the wood around or just beneath a blaze which was made on the tree the same year in which the bullets had entered it. As both these marks were made during the year 1881, it is at least possible that this year the old pine was used as the background for a target during a shooting contest.

While I was working over the old pine, a Fremont squirrel who lived nearby used every day to stop in his busy harvesting of pine-cones to look on and scold me. As I watched him placing his cones in a hole in the ground under the pine-needles, I often wondered if one of his buried cones would remain there uneaten, to germinate and expand ever green into the air, and become a noble giant to live as long and as useful a life as Old Pine. I found myself trying to picture the witnessed but of which he had made no record. I wondered if he had enjoyed the changing of seasons. I knew that he had often boomed or hymned in the storm or the breeze. Many a monumental robe of snowflowers had he worn. More than a thousand times he had beheld the earth burst into bloom amid happy songs of mating birds; hundreds of times in summer he had worn countless crystal rain-jewels in the sunlight of the breaking storm, while the brilliant rainbow came and vanished on the near-by mountain-side. Ten thousand times he had stood silent in the lonely light of the white and mystic moon.

Twilight was fading into darkness when I arose and started on my night journey for the summit of Mesa Verde. When I arrived at the top of the Mesa, I looked back and saw a pyramid of golden flame standing out in the darkness.

Attached to the book is a letter to the publisher from Philip Ashton Rollins, of 28 East 78th Street, New York which we have also reproduced here –A.B. & M.C.

To Mr. Charles Lathrop Pack
Lakewood, N. J.

December 17th, 1926

My Dear Charles:—

In Enos Mill's book 'The Story of a Thousand Year Pine' he speaks of having discovered marks made on the tree by an axe and by bullets in the year 1881. He fixed this date of 1881 by counting the rings of growth in the tree.

A few years after the publication of the book Mr. Mills received from a hunting guide a letter which I have seen. In that letter the guide said that though he did not know Mr. Mills he took the liberty of writing him that the date of 1881 was correct. He knew it to be correct because he personally was the man who in the Autumn of 1881 axed the tree and fired rifle shots into it.

With warm regards, I am
Your affectionate brother,
PHILIP

CHAPTER TWO: OF LEAVES, ECOLOGY AND RESERVATION

OF LEAVES

It is to caution against injury to a plant's leaves that is the reason for my writing this chapter.

Leaves are like lungs in an animal, uptaking gaseous nutrition and expelling gaseous wastes[52]

Leaves are the parts of the plant that perform the same service to sap as the lungs of an animal do to the blood. They purify the fuliginous[53] vapors[54] received in the circulation of the sap.[55] And, besides the purification of the sap, leaves function to aid the nutrition of the plant: vital airborne nutrients enter through the leaves.[56] Since leaves resemble lungs so much, though it is impossible to

[52] The difference between aqueous matter and gaseous matter is great enough to require specialized organs for each. Lungs and leaves are just as important as stomachs and roots, but each deals with a different state of matter. Likewise, other organs in the body are specialized. Tull does not discuss other organs of plants because he approaches physiology from a practical, agricultural standpoint: it is through the leaves and roots that the farmer best helps their plants. –A.B. & M.C.

[53] "Fuliginous" is a word that means a type of "soot" or "smoke." Tull's uses this word to convey an air made impure, contaminated, poisoned, or, with modern understanding, infused with "waste" carbon or oxygen. Dr. J. H. Kellogg, a pioneer in human nutrition science and microbiology, through his experiments and in coordination with Louis Pasteur, confirms many of Tull's understandings in his book, *Autointoxication or Intestinal Toxemia*, originally published in 1918. Of special note here is that "the carbon dioxide [produced through digestion in the human stomach] escapes through the lungs with the greatest facility." (page 175). Dr. Kellogg's work provides insight not only to how sap or blood circulates, but how all the tissues of a body are interconnected. –A.B. & M.C.

[54] Tull's words, "...fuliginous Steams..." was changed to "fuliginous vapors" to prevent unintentional confusion with the word steam: steam could be understood to mean only water vapor. –A.B.

[55] These fuliginous vapors are the unfit parts of the food (and perhaps some decayed particles that fly off the vessels through which the blood and sap pass, respectively).

[56] Tull's words were "Besides which use, the Nitro-aerious Particles may there enter, to keep up the vital Ferment or Flame." The "Nitro-aerious Particles" has been interpreted to mean particles of fertilizer (consistent with the contemporary usage of the word, "niter"). The editor has interpreted "the vital Ferment or Flame" as a descriptor of life (the phrase, "vital flame," was still commonly used for that description at the time of the editing; when someone is remarked to be dead or dying, their "vital flame" is extinguished). Thus, the modern understanding that nutrients enter through the leaves coincides with Tull's ancient understanding of Nitro-aerious Particles enter

observe the fineness of the plant's vessels and slow motion of the sap, it is reasonable to believe that they provide similar services to the organism as this can be proven without direct observation.[57]

Plants rely on their leaves for the communication of gasses with the atmosphere, exhaling water and wastes through their leaves, and taking nutrients from the atmosphere; plants create clouds and rain to help their growth

Mr. Papin shows that air will pass in leaves and out through the plant at the roots, but that water, while passing in through the roots, will not pass out at the leaves. [58] He shows also that if

through the leaves to keep up the vital Flame. This is, in fact, quite true: the gasses of the atmosphere, required for life, do enter from the leaves as easily as toxic wastes are emitted from them, and both fertilizers and herbicides applied to leaves will be taken up by the plant. –A.B.

[57] Tull's words were, "since leaves do so much resemble Lungs, in the Anatomy of their Organs, 'tis very reasonable to believe, they imitate them in their Office; tho' the fineness of the Vegetable Vessels, and slow Motion of the Sap, will not admit a demonstration of the Sap's circulation by Ligatures, but we have other reasons which do sufficiently prove it." —A.B.

[58] Water does pass out through the leaves in a gaseous form. The United States Geological Survey, in their publication *the Water Cycle (Water Science for Schools) – Transpiration* (http://ga.water.usgs.gov/edu/watercycletranspiration.html) remarks that

Plant transpiration is pretty much an invisible process—since the water is evaporating from the leaf surfaces, you don't just go out and see the leaves "sweating". Just because you can't see the water doesn't mean it is not being put into the air, though. During a growing season, a leaf will transpire many times more water than its own weight. An acre of corn gives off about 3,000-4,000 gallons (11,400-15,100 liters) of water each day, and a large oak tree can transpire 40,000 gallons (151,000 liters) per year...

...Transpiration is the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapor and is released to the atmosphere. Transpiration is essentially evaporation of water from plant leaves. Transpiration also includes a process called guttation, which is the loss of water in liquid form from the uninjured leaf or stem of the plant, principally through water stomata.

Studies have revealed that about 10 percent of the moisture found in the atmosphere is released by plants through transpiration. The remaining 90 percent is mainly supplied by evaporation from oceans, seas, and other bodies of water (lakes, rivers, streams).

Plants put down roots into the soil to draw water and nutrients up into the stems and leaves. Some of this water is returned to the air by transpiration (when combined with evaporation, the total process is known as evapotranspiration). Transpiration rates vary widely depending on weather conditions, such as temperature, humidity, sunlight availability and intensity, precipitation, soil type and saturation, wind, land slope, and water use and diversion by people. During dry periods, transpiration can contribute to the loss of moisture in the upper soil zone, which can have an effect on vegetation and food-crop fields.

The amount of water that plants transpire varies greatly geographically and over time. There are a number of factors that determine transpiration rates:

- *Temperature: Transpiration rates go up as the temperature goes up, especially during the growing season, when the air is warmer due to stronger sunlight and warmer air masses. Higher temperatures cause the plant cells which*

leaves have no air, a plant will die; and if the plant is placed in a container sealed with wax to make it airtight, with the roots placed in water *in vacuo*[59] and the plant's leaves placed outside the container to have access to air, the plant will live and grow.

Dr. Grew, in his *Anatomy of Plants*, mentions vessels in the leaves that he calls "networks," "cobwebs," "skins of silk," etc. But he also mentions the multitude of "air bladders" in them. These I take to be of the same use in leaves as the vesiculae are in lungs. Leaves are to plants like lungs that are inverted, broad and thin.

Lungs being situated within an animal's body, their vesiculae could have no communication with the atmosphere without the trachea and bronchia. And, even with the trachea and bronchia, the air would be intercepted by the fuliginous vapors were those vapors not expelled by expiration. A want of communication with the atmosphere is the cause of asthma—a disease leaves are not affected by because their vesiculae are always contiguous to the nutritious[60] air that continually presses against them.

Sanctorius, who by his experiment with the Static Chair found that 5/8 of the nourishment (or weight equal to it) taken by a man passes off by unobservable perspiration, could he have invented a method to calculate the quantity of that part of those perspirations that pass through the trachea

control the openings (stoma) where water is released to the atmosphere to open, whereas colder temperatures cause the openings to close.

- *Relative humidity: As the relative humidity of the air surrounding the plant rises the transpiration rate falls. It is easier for water to evaporate into dryer air than into more saturated air.*
- *Wind and air movement: Increased movement of the air around a plant will result in a higher transpiration rate. This is somewhat related to the relative humidity of the air, in that as water transpires from a leaf, the water saturates the air surrounding the leaf. If there is no wind, the air around the leaf may not move very much, raising the humidity of the air around the leaf. Wind will move the air around, with the result that the more saturated air close to the leaf is replaced by drier air.*
- *Soil-moisture availability: When moisture is lacking, plants can begin to senesce (premature ageing, which can result in leaf loss) and transpire less water.*
- *Type of plant: Plants transpire water at different rates. Some plants which grow in arid regions, such as cacti and succulents, conserve precious water by transpiring less water than other plants.*

In fact, that 10% of atmospheric water can have profound effects close to the great forests that are responsible for much of it. "Rain forests" are a kind of climax vegetation that produces its own localized atmosphere. The amount of transpiration in a forest results in clouds and rainfall that helps the plants grow. Likewise, the 3,000 – 4,000 gallons released by an acre of corn every day helps the corn grow by reducing evaporation from the soil and the plants: eventually, like a rain forest, the transpiration of vegetation can result in a beneficial equilibrium of humidity. —A.B. & M.C.

[59] "In vacuum." Translation by Aaron Brachfeld

[60] Tull's word was "nitrous." While it is true that the atmosphere is mostly nitrogen, his term has been interpreted by the editor to be a continued reference to the concept that the air is nutrition for a plant. –A.B. & M.C.

from the lungs, I believe he would have found the most of it to pass that way[61]: when blood enters the lungs of a person from the right ventricle of the heart, it is so full of fuliginous matter that its color is blackened with it. The blood in the heart's left ventricle, being purified of the fuliginous matter, becomes a pure florid red color. In cold weather, vapors may be seen to issue out from the trachea in great quantities.[62] This vapor is constantly supplied by the nourishment taken in at the lacteals of the guts.

Sap Circulates to the Leaves and from the Leaves

Though it is impossible to observe a circulation of the sap through the leaves because the sap moves slowly and through such small vessels, there are other ways prove the circulation of the sap through vessels to the leaves from the roots:

A young potato is nourished by its mother plant at the end of a white string. It must have its nourishment from the mother plant because the young potato and string, being laid on tiles, could have no nourishment from the earth—and yet, with experiment, I found that the new potato will grow large. This shows that material is carried from the leaves to the root. Further evidence may be gained by observing how, when salt is bound to the white string, the salt will pass from the root to the leaves, where it may be tasted.

Leaves do not only remove waste from the plant's body, leaves undertake the photosynthesis of sugar and provide necessary gasses from the atmosphere

A quantity of matter nearly equal to that received by the roots is constantly carried off, and I believe that nobody has ever doubted before that the matter had its chief exit from the leaves. But I think that it is not likely that all those curious vessels, which appear in the texture of a leaf, should be designed for the waste material (received from the roots and sap) to pass once through and from there fly away. I think that the matter received by the roots might just as well pass off—without the use of leaves—at the place where the matter is received by the plant.[63]

While Mr. Hales, in his *Vegetable Staticks*, found that a plant imbibed and perspired less water when its leaves were pulled off than when they were on, this might be partly from the contraction of the vessels exposed to the air at the wound where the leaves were broken off. Mr. Hales also shows that the quantity of liquid that passes through a leafless plant in summer (though it is less than what passes through a plant that has its leaves on) is vastly greater than what passes through the same plant in winter. A plant with a great quantity of nourishment in summer and no leaves will die while a plant little nourishment in winter and no leaves will live.

By Mr. Hales, it appears to me that the taking in and passing of nourishment will not keep a plant alive unless it has leaves in proportion to that quantity of nourishment taken in. It cannot be

[61] See Mr. Papin's *Experiments of the Pneumatick Engine*. It appears that water will pass out of leaves, but not from without into them. And, nothing can be found to pass in or out by the bark—unless the bark is cut.

[62] Plants also exhale "great quantities" of water vapor, carbon dioxide, oxygen and other chemicals. –A.B. & M.C.

[63] Waste gas and liquid is, indeed, also expelled from the roots. –A.B. & M.C.

denied that leaves are absolutely necessary to the life of a plant. If they are, I think that it must be either on account of the leaves conveying something from the nourishment drawn from the roots, or else bringing something to the nourishment drawn from the roots. I do not believe that it is the former because the conveyance of something from the nourishment drawn from the roots can be done without leaves (Mr. Hales' plant survived in winter). It must be that the leaves secrete something to the sap circulated through them.[64]

As the lungs of an animal would be no benefit to the animal if the blood, after it was purified in them, was not returned to the body, so too would the secretion made by the leaves be of no benefit to the plant if none of the sap sent to the leaves were returned back to the plant. The air, taken in by the leaves, could be no use to the rest of the plant unless the leaves passed that air into the sap. In proving that the leaves secrete something into the sap, the circulation of sap is proved.

And yet Mr. Hale has a suspicion against the circulation of sap! He takes his chief arguments from the quick passage of nourishment drawn from the roots through the plant, supposing that nourishment to be sap. But this supposition is as unreasonable as to suppose that the wine we drink and piss[65] out to be our blood! And, indeed, the quicker and more wine a man will drink, the quicker a man will begin to pass wine. But the man who drinks wine continuously—without taking his mouth from the tap until he is finished pissing—would have as quick a passage for the wine as any plant in all of Mr. Hales's experiments had for water...Mr. Hale has no proof against the circulation of the blood, and no proof against the circulation of the sap.

Mr. Hale says, in his chapter *of Vegetation* (pages 324-325), says that

...'tis possible Dew, Rain, &c. are ambibed by the Leaves, and are the Materials of which the more fubrile and refined Principles are form'd...That Leaves do in some Measure, the same Office for the Support of Vegetable Life that lungs do for the Support of Animal Life; Plants drawing through their Leaves some part of their Nourishment from the Air...

But if this nutritive matter did enter at the excretory ducts of leaves, as Mr. Hales supposes, while the plant was in an imbibing state, then the nutritive matter from the air would have to be expelled

[64] It is now known that leaves secrete sugar to the sap. The "photosynthesis" of sugar from the energy of light is a complex chemical reaction that is only now becoming fully understood. Carbon dioxide from the atmosphere and water (usually from the soil) are bound by the energy of light to make carbohydrates (water carbons, or "sugar"). The byproduct of this reaction is oxygen. Some creatures have similar processes that produce Carbon monoxide, or other nutrients entirely. Some plants have the ability to use less or almost no atmospheric carbon dioxide, an advantage in hot dry conditions when the plants wish to reduce transpiration of water by "holding their breath" and closing their stomata. At night, when the plants must use their stored sugars (as animals and other creatures unable to manufacture sugar must do), they release Carbon dioxide. Some farmers will plant densely so that the Carbon dioxide is held close to the plants and they might breathe it in during the morning hours and save some effort in collecting the Carbon dioxide from the atmosphere twice. In closed environments, some farmers will feed their plants Carbon dioxide gas during the day or under lit conditions to increase sugar production. –A.B. & M.C.

[65] [Sic] –A.B. & M.C.

again at the same duct it entered by the perspiring pressure.[66] Such an intake of nutriment would be of little or no use to the sap!

And to think that the nourishment and sap of a plant passes off together is no less absurd than to think that the blood and chyle pass off together when an animal perspires.

What purpose should the sap be purified in the leaves if the sap is not returned to the plant by other vessels? Is it not more probable that the nutritive particles of the air which, Mr. Hales proves, are so plentifully received in leaves should invigorate the sap returning to the plant? How could the leaves nourish the plant if they only purified the sap? If there was no circulation, the sap and all other juices would pass off together at the leaves...and then there would be no manner of use for the vessels of the leaves as purifiers!

Leaves alter the nutrients received by the roots

It would be very strange, if what is pure earth and water when it enters the root should be transformed into such different juices by passing once through a plant in so short of a time. The juices must either become sap in the root or else, upon the juices leaving the roots not much different from earth and water near the root, the higher the juices go in the plant, the more different and altered the juices become. But even though we find that sap in at the bottom and top of a plant to the same, we cannot suppose the roots to alter the water and earth.

Leaves alter the nutriment received by the roots. If leaves did not provide this necessary work, the lives of plants would not, in all probability, so entirely depend on the use of leaves as they appear to do. This is always proved (tragically) by those who would kill their sanfoin by suffering it to be fed upon by sheep. Avoid injury to a plant's leaves.

This is certain from all experience: no vegetable whatever can live long without leaves and will very soon die if leaves are pulled off as fast as they appear.

Leaves are so necessary to plants that nature has, in all perennial plants, provided a stock of them, as Dr. Grew observes in autumn (though the leaves are not usually grown until the following spring, when they open and increase gradually in proportion to the circulation of the sap and the quantity of food the plant receives to be circulated). But, besides the autumnal buds of Dr. Grew's, there is another set of buds that appear in spring and are expressed about mid-summer. These spring buds save the lives of the mulberry trees when their first leaves are taken off for the silkworms

Yet these second leaves would not suffice to serve the trees if the first leaves were stripped completely. Those who gather mulberry leaves always leave behind some of the tails or "foot stalks" with a little bit of the leaves for the trees to live by until the new leaves grow large enough—much as how some men have been found to live (but not long, I suppose) by a small part of their lungs, the rest having wasted and dried away in the consumptive or asthmatic diseases.

[66] It is possible for this to occur when matter is in a state of unpressurized gas, as the incoming particles would not obstruct the outgoing ones. The rate at which gasses flow in and out of the plant is slow enough that there is no obstruction by the incoming particles from the outgoing particles. –A.B. & M.C.

Jethro Tull's Supplement

The method and purpose of circulation; sap is like blood; the presence of arteries and veins and capillaries in plants

Chyle (which is mistaken by some for sap) enters at the roots and progresses—except in cases of unequal pressure—to the leaves, and then separated into such parts of it as are proper nourishment for the plant, the rest perspired as waste.

In grafting, it is true that the juice of a stock, mixing with that of the scion, may a little alter the flavor of its fruit (a pear grafted upon a quince may be mended, but if grafted upon a white thorn will be worsted) but this may very well be from that little alteration the sap receives in circulating through the vessels of the stock.

True sap never passes out nor in at the leaf, nor at any other part of a plant unless the plant is wounded; true sap must be made (of chyle) within the plant. True sap must either circulate or stagnate, and stagnation of sap is as sure a death to a plant as stagnation of blood is to an animal, for without motion it would corrupt and putrefy.

The motion of true sap must be circular because, it being proved that the chyle is joined with the sap in the leaves and allowed that sap is made of (made nourishing by) chyle (the allowing of which, I believe, nobody who considers the evidence will deny), it follows that the sap passes from the leaves to all parts of the plants as blood does from the lungs of an animal for the nourishment of the whole body. If such part of it as is not spent in nourishing the plant were not returned back to the leaves, there could be no sap in them to mix with the chyle. This motion from the leaves and returning to them I call "circulation," no matter the means by which it is performed.

There are other ways by which circulation may be performed beside pulsion and without the necessity of a heart, but far be it from me to attempt explaining the manner of it. I am inclined to think trusion, the act of pushing and pulling, the most likely in plants. As I remember, Mr. Bradley has accounted for it in this way: as heat rarefies the sap in one part of a plant more than in another, the heated sap requires more room and consequently expands itself, moving further by thrusting or pushing on that which is next to it.

If the analogy holds between sap and blood in other respects between a plant an animal, there must be in a plant vessels something analogous to arteries and veins—and therefore even to capillaries (because it is said by the learned that blood does not nourish the vessels by passing through their cavities, but by that which is sent out of the capillary arteries into the parenchyma, or connective tissues[67]). How very unlikely is it then, if this analogy holds, that the plant should be immediately nourished by the crude chyle passing once from the root through the cavities of the chyle-vessels up to the leaves, and thence all into the atmosphere?

Nobody doubts of the circulation of blood in all animals even though in many very small ones it cannot be proved by demonstration. There is no more reason to doubt of it in plants than in oysters, mites, and in many species of insects too minute to be seen by the naked eye.

[67] From thence, it passes into the cells by osmotic pressures, and through the activity of the cells themselves. –A.B. & M.C.

The argument against circulation from the great quantity of water imbibed and perspired by sunflowers answered by how sometimes more resources are consumed than are necessary for life

Yet there is still an argument brought against this circulation: the great quantity of water imbibed and perspired in a short time by the sunflower. This argument is answered by the very short and direct passage which that water has from the root to the leaves (that perform the office of kidneys to the redundant water in the chyle): though the chyle in an animal has but a short passage from the lacteals to the blood, it is still much longer than the passage of the vegetable chyle.

The animal chyle, though not moved by pulsion, arrives soon at the subclavian vein. There joining with the blood, the chyle goes with it immediately to the heart, whence it is by pulsion driven through the lungs (being therein more intimately mixed and also purified) and that which is not thence thrown off by expiration has not a long journey by the emulgents to the kidneys, which separate and send down a greater or lesser quantity of urine in proportion to the quantity of liquor drunk.

And sometimes, with men as well as with plants, much more is drunk than is necessary: as I remember two Swiss soldiers at Montpellier were carried before the governor by their landlady for refusing to pay for fifty-six pots of very strong wine, which they drank at one sitting: their dispute was about the odd pots, they said, they never used to drink more than fifty in that time; but the woman insisting on her proof, the governor paid for the odd.

A Montpellier pot contains three English pints.

Now, I suppose this quantity is vastly greater than is necessary for a man to drink in that time, but yet it was not so much unnecessary as the quantity of water was to Mr. Hales's sunflower. I am in no doubt that his sunflower would have thrived well with the fiftieth part it imbibed because I have seen a sunflower grow very well in dry rich ground in a dry summer when it might drink with no greater quantity than a man in his regular ways of living, bulk for bulk.

Arguments against the circulation of sap from how trees bleed sap from the lower and not the upper part of a notch answered by demonstration that less sap flows downward than upward

The argument against the circulation of sap that is taken from the liquor issuing plentifully out of the lower part and not from the upper part of a notch or a disbarked gap of a tree or branch set in water is answered by showing that the greatest part of that liquor passes out of the leaves without descending and so cannot issue out at the upper part of the gap. And the sap, being thicker and in less quantity, has probably a much slower motion and is not so apt to pass out at a cut as the aqueous chyle is: a plant never bleeds to death except when the sap is very much diluted by a great mixture of chyle.

The lungs cannot do the office of kidneys in an animal because, being at such a distance from the open air, the great quantity of liquor necessary to be sent off (though rarefied to vapor) would cause suffocation in the bronchia and trachea. But leaves, being in contact with the air, can execute the office of kidneys without that danger. Even in some animals, nature has other ways of discharging the aqueous part of the blood besides kidneys, especially in aquatic animals.

Arguments against circulation that the scions of grafted trees die if different species are grafted together answered by contrary evidence

This is offered by Equivocus against the circulation: we see that when the nature of a stock is very different from the scion the juices made by their different vessels are so disagreeable to each other that one or both (but always the scion) will die.

But we see also that the same stock can produce different sorts of pears because the ovaries of plants self-contains all the fruit and plants that ever will proceed from it. We find by inoculation, that a bud is an entire little tree, containing within itself its proper seed, and all the trees that ever can processed from it. Though the sap of the stock may agree with the scions as to nourish them all, the juices of the scions are different from the stock; the juices of the stock cannot change the sort of fruit of the ovaries, but only nourish them.

Arguments against the circulation of sap from amputation as groundless as arguments against the circulation of sap from cloning by cutting; an explanation of why roots are emitted from the correct side of the cutting

The last objection I shall speak to is this:

It is asked by Equivocus, "how goes the circulation when a part is cut off from a plant?" "Why," I say, "it goes on as the circulation of blood does in a man upon the amputation of a leg or an arm."

As for the part cut off from the plant, provided that it is cut at a proper season to be stuck in the ground, if it have a spongy rind it will grow and become a new plant. The resulting roots, being the chyle-vessels, are sent out from that part of the bough which is in the ground and show that these chyle-vessels pass all over the plant. The bough sends out leaves also, which shows that buds are contained all over it.

Why the roots should choose to strike out in the earth rather than the air, and the leaves in the air rather than in the earth, I cannot tell: it is by an unknown sort of mechanism, or rather instinct, which I can no more pretend to explain than I can the cause of gravitation.[68]

I might urge another argument against those who assert that the sap is made by the bark in its ascent only: if that were so, the sap must be more pure the higher it ascended and pass of into the atmosphere in its greatest perfection. This would intimate that sap was not designed by nature for nourishment of plants, but to be thrown away as useless, when its purpose is most useful.

[68] The plant senses the water and chemicals of the soil, as well as gravitational pull, and modifies the bud to produce either roots or leaves. This sensory method was discovered by Charles and Francis Darwin. —A.B. & M.C.

Supplement of the Fifth Edition

Kinds of Leaves

Botanical science has defined the several kinds of leaves. We have provided an identification guide, useful for identifying wild plants, but also for training the eye to recognize the different ways plants have adapted themselves and specialized their organs.

The best advantage to learning how to identify plants is that it requires the training allows an examination of a plant: consider what its shape is and what advantage the plant gains by that shape. Examine its role in the ecosystem, what creatures it interacts with, and you will, by training your mind to observe the various shapes there exist in all of nature, understand what advantage that specific shape has to offer in this case. There are a limited number of variations, and each serves a purpose.

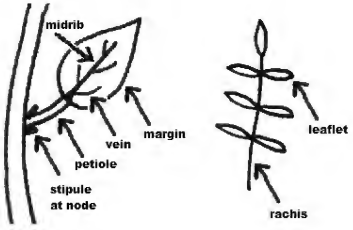
Study, as Tull did, the lineage of each plant: where it originated, its relatives and ancestry, and see how a solution from cons past has new practical applications for a modern individual.

Leaves are adapted to both environmental demands of temperature, moisture and weather. Leaves are also sometimes present in modified forms that imitate the function of roots, stems, or reproductive organs. Within a plant, there is considerable variation: some trees try to shade themselves from a scorching sun by growing bigger leaves on top than on bottom; other trees, hungry for light, will grow bigger leaves on bottom than on top. Some leaves appear to be nothing more than thorns or spines and serve both to shade a hot plant and protect it against enemies: these plants, having no thorns, were required to modify their leaves to act as thorns and their stems to act as leaves!

Some leaves have a shape that quickly drives water off it to reduce the risk of infection in moist environments. Other leaves catch the moisture with bizarre shapes so they might drink from their leaves as well as their roots. Hair insulates and, depending on how it is shaped and directioned, facilitates water flow or inhibits it. Some leaves by their shape break up drying, cold or hot winds better than others, which encourage air flow.

Some leaves have veins that expose many small capillaries to the air, others, growing in a more hostile environment, do not. Some plants shape their leaves around the needs of the veins, others make their veins accommodate the shape of the leaf – this lends some insight into which is more important to the plant.

LEAF PARTS



- **Leaflet** – has appearance of leaf, but is arranged with other leaflets along a rachis (instead of along a stem or branch)
- **Margin** – the leaf edge
- Midrib – the center vein that stretches from petiole to tip, often from which other veins emanate
- **Node** – the junction of the petiole and the stem
- **Petiole** – the leaf stem
- **Rachis** – the "midrib" for a compound leaf, to which all the leaflet's midribs are attached
- **Stipule** – located at the node, appearance of tiny pair of leaves. Sometimes these fall off and leave a "scar"
- **Vein** – the vasculature of the leaf, often forming visible patterns

LEAF SHAPES

- **Cordate** – Heart shaped



- **Elliptic** – Oval, with the widest part in the center and symmetrically curved margins



- **Lanceolate** – Oval, with the widest part close to the base, leaf is narrow



- **Linear** – Leaf edges are parallel, leaf is narrow



- **Needle** – long and very narrow, like a sewing needle, common on pine family

- **Oblanceolate** – Oval, with the widest part close to the tip, leaf is narrow



- **Oblong** – Leaf edges are parallel, leaf is wide



- **Obovate** – Oval, with the widest part close to the tip



- **Obtriangular** – widest part at the tip, tapering to the base



- **Orbicular** – Round



- **Ovate** – Oval, with the widest part close to the base, leaf is wide



- **Reniform** – Kidney shaped



- **Scale** – small, flattened to stem



- **Spatulate** – Spatula or club shaped



- **Spine** – Thorn-like, found on cactus family
- **Triangular** – widest part at the base, tapering to the tip



LEAF SHAPES (TIP)

- **Acuminate** – pointed, with angle less than 45degrees

- **Acute** – pointed, with angle between 45 and 90 degrees



- **Cuspidate** – triangular "tooth-like" extension



- **Mucronate** – very small point extension



- **Notched** – indented or "cut"



- **Obtuse** – pointed, with angle greater than 90 degrees



- **Rounded** – no point, forms a smooth arc



- **Truncate** – flat, forms a straight line perpendicular to midrib



LEAF SHAPES (BASE)

- **Attenuate** – slopes in a concave curve towards petiole



- **Auriculate** – extends past petiole attachment, forms an "earlobe" on each side (rounded tips)



- **Cordate** – smooth arc on each side of petiole attachment



- **Cuneate** – wedge shaped, slopes in a relatively straight line towards the petiole



- **Hastate** – extends past petiole attachment, flares out and forms a point on each side



- **Oblique** – unequal, so that the leaf joins the petiole at a different place on each side



- **Rounded** – smooth arc continues across petiole attachment



- **Sagittate** – extends past petiole attachment, forms a point on each side



- **Square** – flat, forms a straight line perpendicular to midrib



LEAF SHAPES (MARGIN)

- **Cleft** – sharply cut, but cuts do not reach midrib or petiole



- **Crenate** - "scalloped," similar to serrated but tips are rounded



- **Dentate** – "toothed," like serrated but tips are more triangular and not angled



- **Dissected** – "fern-like," many-parted and usually narrow



- **Entire** – straight, no lobes, serration or other indentation



- **Incised** – numerous lobes at various depths



- **Lacerate** – unevenly serrated, appears torn



- **Lobed** – cut in "scoops"



- **Parted** – Lobes or clefts almost reach the midrib or petiole, looks similar to "palmate" arrangement but not divided enough to become separate leaflets



- **Pinnatifid** – numerous lobes at similar depths



- **Revolute** – curled, usually towards the underside

- **Serrated** – "toothed," with tips of teeth pointed like a saw and at an angle



- **Undulate** – wavy



LEAF SHAPE (VEINS)

- **Dichotomous** – with veins repeatedly branching into equal pairs



- **Netted** – with veins forming a network



- **Palmate** – with three or more veins arising from common point near base of blade



- **Parallel** – with veins extending from base to apex, essentially parallel



- **Pinnate** – with secondary veins arising from midrib



LEAF ATTACHMENTS

- **Basal Sheath** – In pine family, the small cap that encloses the bases of each cluster of needle leaves



- **Clasping** – NO petiole, attaches directly to the stem at the base of the leaf, with the base partially wrapping around the stem



- **Connate** – No petiole, attaches in a way that appears that the stem grows through the junction of two leaves that are united at their bases



- **Peltate** – petiole attaches at the middle of the leaf



- **Perfoliate** – NO petiole, attaches in a way that appears that the stem grows through the leaf



- **Petiolate** – petiole attaches at the base of the leaf



- **Sessile** – NO petiole, attaches directly to the stem at the base of the leaf



- **Sheath** – NO petiole, attaches directly to the stem at the base of the leaf, with the base wrapping down the stem and layered with the next clasping leaf along the stem



LEAF ARRANGEMENTS

- **Alternate** – One leaf at node, so leaves grow alternately along stem or branch



- **Bipinnate** – a compound leaf, several pinnate leaves arranged along a shared rachis



- **Fascicle** – In pine family, several leaves attached together with a basal sheath



- **Opposite** – Two leaves at node, so leaves grow in pairs along stem or branch



- **Palmate** – a compound leaf, four or more leaflets emerge from same point at the petiole, looks like rays or fingers



- **Pinnate** – a compound leaf, leaflets arranged opposite along a rachis.
 Odd Pinnate has a terminal leaflet (and thus has an odd number of leaves)
 Even Pinnate lacks a terminal leaflet (and thus has an even number of leaves)



- **Rosette** – Several leaves all emerge from single point near ground level and are arranged as rays or "rose petals"



- **Trifoliate** – a compound leaf, three leaflets emerge from the same point at the petiole



- **Whorled** – Three or more leaves at node, so leaves grown in a circle around stem or branch



LEAF HABIT

- **Erect** – grows upright, not leaning



- **Sprawling** – grows at multiple angles at once, also called "spreading"



- **Ascending** – grows at an angle, appears to lean



- **Creeping** – grows along the ground



Flowers are modified leaves

Flowers are modified leaves; they first appeared in the Triassic period (about 200 million years ago). The poinsettia plant (*Euphorbia pulcherrima*) provides an excellent example of a modern-day leaf flower. Native to Mexico and Guatemala, it is named after Joel Roberts Poinsett, the first United States Minister to Mexico who introduced the plant to the United States in 1828.





OF ECOLOGY

Sky and soil are distinct environments, plants adapted to live on their boundary; plants exchange chemicals between soil and sky, bringing sending chemicals skyward and burying lighter chemicals; plants improve the cycling of water, and all the cycling nutrients

Plants live on the complex boundary between the two very different environments of soil and atmosphere. The roots and the leaves of a plant exist in such different places that, should the plant be reversed as they are by mouldboard plows (the leaves are buried and the roots exposed to air), the plant must either die or regenerate roots below ground where its leaves now are and regenerate leaves where its roots now are (and some plants, such as grasses, are adept at this regeneration!).

Through their stalks and trunks, plants exchange chemicals between soil and sky, bringing light's energy and the lighter atomic elements and molecules (which would otherwise not easily settle into the soil to be acted upon by microorganisms) beneath this critical boundary, and bring heavy chemicals that would not normally vaporize into the atmosphere. Also importantly, the plants continue the water cycle, giving the vapor no rest but sending it skyward again

The USGS in their publication *Water Science for Schools: The Water Cycle* (http://ga.water.usgs.gov/edu/watercycle.html) explains that "Earth's water is always in movement, and the water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. Since the water cycle is truly a 'cycle,' there is no beginning or end. Water can change states among liquid, vapor, and ice at various places in the water cycle, with these processes happening in the blink of an eye and over millions of years. Although the balance of water on Earth remains fairly constant over time, individual water molecules can come and go in a hurry. The water in the apple you ate yesterday may have fallen as rain half-way around the world last year or could have been used 100 million years ago by Mama Dinosaur to give her baby a bath."



From the oceans, the water evaporates, and condenses into clouds, which then condense more over the land to form ice, rivers and ponds. These freshwaters either find their way directly

back to the ocean, are stored in the rocks they sit upon or are absorbed and transpired by plants back into the atmosphere. As discussed in the Chapter on Roots, plants can increase the amount of water vapor in the atmosphere enough to induce rain!

The history of our atmosphere lends the insight needed to understand Gaia hypothesis, and prove Montesquieu's theory that every individual's interests lie in the betterment of the whole; life, as a geological phenomenon, on large and small scales, makes its environment more suitable for life by harnessing solar energy – why Earth is different from all other planets in the Solar System

All planetary atmospheres in the inner Solar System (except Earth) are in a state of equilibrium. Mars and Venus have atmospheres that are more than 95% Carbon Dioxide, less than 3.5% Nitrogen, less than 0.13% Oxygen, 0% methane and have an average surface temperature that forbids the formation of liquid water (either by being too hot or too cold). Our planet's atmosphere is different: it is mostly Nitrogen (79%), Oxygen (21%) and Methane (1.7ppm), with only trace amounts of Carbon Dioxide (0.03%). Life preserves vast oceans of water on Earth from evaporation into space when all our neighboring planets are (mostly) dry.

The reason for this difference is because life transforms solar energy into mechanical, chemical, electrical and thermal energy. This is a definition of life: life is an agent of energetic change. Life is, as Charles Darwin described, a geological force upon this planet that, by transforming solar energy into various other forms, affects the planet itself. Life generally affects the planet so that the conditions observed today are much like the conditions observed billions of years ago, so that these conditions will remain constant even billions of years from now. Most notably, life maintains a near-constant temperature on Earth against increasing solar radiation, and against catastrophes that would otherwise disrupt the environmental equilibrium most beneficial to life.

The effects of life can be mathematically predicted using what has become called the Gaia hypothesis (developed by Dr. James Lovelock): life is nothing but an agent by which chemical changes occur, and the past and future of life is easily predicted if the quantities of the chemicals present at any given time are known. "Gaianism" reminds us that Darwinian evolution selects those species for survival that best maintain the conditions they (and all other creatures) require to survive: we are selected by our ability to affect our planet through chemical, mechanical, electrical and thermal energy.

Lovelock, ingeniously, began his modeling with simple life systems. At first, he modeled how 3 species of daisies would behave in the context of Darwinian evolution and the single resource of heat. The theoretical planet had the sunlight increase gradually upon it, modeling our own increasing solar radiation from the sun. He called the planet "Daisyworld."

He found that the darker daisies, which absorbed more heat and warmed the soil and the air around them, prevailed at first when the sunlight was dim. As the sunlight warmed with the growth of the star (imitating our own sun's growth), grey daisies dominated the planet. In the end, white daisies, which reflected light and cooled the soil and air around them, succeeded the grey daises. The temperature of the theoretical planet remained constant against the increasing sunlight, imitating the real constancy of our own Earth. When natural heat-increasing properties of the dark daisies ceased to be advantageous, the natural heat-decreasing properties of white daisies began to be advantageous: not only to the individual daisies, not only to the species of daisy, but to the entire planet of daisies.

Adding in more and more shades of daisies, and eventually rabbits and foxes, he found the model more and more accurately predicted the real Earth's temperatures and conditions. Adding in amazing complexity of hundreds of organisms, considerations for atmospheric composition and pressure, volcanic action, asteroid impacts, viral plagues, and many other realities, the model increasingly recreated the real Earth's history.

The Gaian mathematical models accurately describe the history of life on Earth as being a series of responsive adaptations to changing conditions. Life must continually adapt to a changing environment: our star grows brighter and hotter every year, our planet is bombarded by dangerous asteroids and comets. To respond to these crises, life changes the atmosphere and the land to maintain the temperature and conditions required for life. In response to the growing amount of heat from the Sun, life has decreased the greenhouse gasses in the atmosphere and made the surface albedo (a measure of reflectivity) greater over time to compensate for the increased heat from our star (more light reflected into space means a cooler planet). When an asteroid collides and changes the atmosphere by adding dust, water vapor and other chemicals that decrease the greenhouse effect, life reacts by increasing the production of greenhouse gasses and decreasing the albedo.

By integrating mathematical models of how life reacts to the Earth through chemical emissions and albedo, and integrating mathematical models of how the Earth reacts to life through chemical emissions and albedo, integrating understandings of erosion, water temperatures and volumes, and countless other details, Lovelock's models accurately explain the history of our planet. As complex as they are, even looking at albedo reactions is sufficient to explain most of the history of our Earth.

When life first appeared on our planet, there were only microorganisms. These first living creatures ate the numerous poisons that dominated the early Earth. We still rely upon these organisms to eat the human-made pollutants that would otherwise destroy life (such as radioactive and other heavy metals, fossil fuel wastes, pesticides, etc.). They produced great quantities of Carbon dioxide and other chemicals that were far less dangerous to life. These gasses served to insulate the planet and keep what meager heat came from our star. As these pioneers cleaned the planet, there arose new organisms that ate sunlight and the Carbon dioxide to produce wastes of Oxygen.

The waste Oxygen these photosynthesizers produced was bonded immediately to the Iron and Sulfur in the oceans and there was no danger to these early anaerobes of Oxygen poisoning. Carbon dioxide was deposited at the bottom of the sea as limestone while Oxygen was bonded by the Iron and Sulfur. In the presence of life, the Carbon dioxide atmosphere fueled the necessary actions required to keep water from evaporating into space (the Iron and Sulfur would have bonded with the oxygen in the water, and the hydrogen would have fled the atmosphere).

The limestone that was made from this photosynthesis prompted the surface temperature of the Earth's crust to drop and the crust itself to sink: this made volcanoes and earthquakes that yielded even more greenhouse gasses (including Carbon dioxide, methane and others), warming the planet and speeding this chemical process.

Once the oceans of water that are so essential to life were thus secured, the oceans began to accumulate oxygen: they were saturated! When the oceans had stabilized and could no longer absorb any more Oxygen, Oxygen escaped to the atmosphere. But by this point, the Carbon dioxide was almost used up and the Earth began to cool to dangerous levels, the liquid water that was so hard won began to freeze and become poisoned by too much Oxygen. This temperature fluxuation and Oxygen surplus killed much of life on Earth, but the creatures who ate the dead flourished, producing more Carbon dioxide and methane and other greenhouse gasses as they digested the dead

bodies of their fellow creatures. This Carbon dioxide and methane saved the oceans and eventually the ecosystem stabilized.

Those eaters of the dead, those photosynthesizers and those toxin eaters that could tolerate high degrees of oxygen did much better than their anaerobic competitors and were selected by Darwinian evolution: the oxygen allowed a greater energy efficiency that was an advantage to the planet: they could live closer to the surface of the water where Oxygen was greatest, and gain the benefits of solar energy.

However, those who disliked the oxygen hang on even today where Oxygen levels are low in the depths of the ocean, in caves, and even in the guts of animals. There became a great difference between the anaerobic and aerobic life; those who existed before Oxygen and those who existed after. Today, most of the anaerobes live inside the aerobes, helping them digest the foods they eat and process toxins; some live in the soil, where farmers fend them off with tillage. They are everywhere, but never so numerous as they were before an oxygenated atmosphere.

As life began to grow more numerous and more diverse, the production of water vapor as a waste product yielded clouds, which rained upon the soil and allowed the colonization of the land: most rain is even today from evapotranspiration. When the land was colonized, life gained control over the albedo of the land's surface, and better ability to produce the various gasses required to control the temperature of the planet. To gain more land space for life, Gaia reduced the temperature of the planet through Ice Ages that locked up the water as ice to force the sea levels to drop. Deserts were key to this transformation, reflecting light back into space. Vast deserts of sand and ice allow for more total life on our planet.

The experiments of Dr. Stanley L Miller on primordial Earth environments and the spontaneous evolution of life as a geological phenomenon

The work of Dr. Stanley L Miller redefined the human understanding of life perhaps as much as any observation of Charles Darwin, and bears greatly on the work of Jethro Tull.

His work in demonstrating that organic compounds could be synthesized under primitive Earth conditions, published in the essays *A Production of Amino Acids Under Possible Primitive Earth Conditions* (printed in *Science*, Vol. 117, No. 3046, pages 528-529, May 15, 1953) and *The First Laboratory Synthesis of Organic Compounds under Primitive Earth Conditions* (printed in *The Heritage of Copernicus: Theories Pleasing to the Mind*, edited by J Neyman of the MIT Press, 1974), are striking and shocking: life is a spontaneous geological phenomenon.

Miller begins his work by acknowledging that "the idea that the organic compounds that serve as the basis of life were formed when the earth had an atmosphere of methane, ammonia, water, and hydrogen instead of carbon dioxide, nitrogen, oxygen and water was suggested years before he began his experiments (Oparin, *The Origin of Life*, 1938, a translation of the 1924 pamphlet, *Proiskhozhdenie Zhinzi, Moskovkii Rabochii*) and has been given emphasis recently by Harold C Uray and Bernal" and explains how he set himself to test this by recreating that primitive atmosphere and exposing that atmosphere to electricity, imitating the effects of lightning.

20 years later, he was able to write that "it is now generally accepted by scientists that life arose on the earth early in its history. The sequence of events started with the synthesis of simple organic compounds by various processes. These simple organic compounds reacted to form polymers (an example of a polymer is Nylon, in which many molecules of an amino acid are linked

together forming long chains. Hemoglobin, the protein in blood that binds oxygen, is also an amino acid polymer, but there are twenty different amino acids in this polymer and they are linked together in an exactly specified sequence) which in turn reacted to form structures of greater and greater complexity, until one was formed that could be called living."

He was inspired by the fact that the solar system is largely reducing, that is to say that there is an excess of molecular hydrogen, and that the Earth was likely reducing in its early history before it became oxidized, an idea suggested to him by his teacher, Urey. "Urey's point immediately seemed valid to me. For the nonchemist, the justification for this might be explained as follows: it is easier to synthesize an organic compound of biological interest from the reducing atmosphere constituents because less chemical bonds need to be broken and put together than is the case with the constituents of an oxidizing atmosphere."

Miller researched the subject and found that "the action of electric discharges on methane seemed to give a random mixture of hydrocarbons, so I was convinced that I would at least get hydrocarbons as products and probably a random mixture of organic compounds containing nitrogen and/or oxygen; this random mixture of organic compounds would contain, hopefully, a trace of amino acids and other compounds of biological interest." Amino acids, the building blocks of proteins, became the target of observation in the experiment.

It took a week to assemble the experiment, especially to make sure there were no leaks. After reducing the electricity for fear of danger, Miller filled it with the primitive atmosphere and let it run overnight. Two days later, he collected the hydrocarbons and looked for amino acids. He found no amino acids. He then, bravely, increased the electrical discharge to more accurately imitate lightning. One day later he got amino acids.

His teacher, Urey, told him to do it again. This time, for a week. Miller was on hand constantly to ensure that dangerous pressures would not build up. Glycine, alpha-alanine and beta-alanine were present, as were aspartic acid and alpha-amino-n-butyric acid. 110 mg of amino acids were present at the end of the week.

After publication, doubts were raised against his experiment, both against the results of amino acids, and the implications that life could spontaneously evolve out of geological actions. He answered all the objections, and there were no more doubts raised against him or his work. In doing so, he demonstrated other amino acids could evolve out of the same process. Others repeated his work and came up with similar results.

In 1969, a meteorite fell in Murchison, Australia and was subjected to strict analysis. Within the space rock was found amino acids. The result was to confirm Miller's work, and extend its implication to include the spontaneous generation of life not only through geological processes, but through celestial processes, that life is likely to exist on other planets besides our own.

The understanding that life is a geological phenomenon would come to inspire Dr. James Lovelock to define its geological properties through the *Gaia Hypothesis*, and provide better insight into why humans farm, and how to undertake agriculture better, and how agriculture impacts the cycling of air, water and soil on the planet.

The collaborative unconscious actions of all living creatures responding to Darwinian evolutionary pressure create a feedback cycle between life and its environment, allowing the biosphere as a whole to react to changes; humanity's powerfully important role on Earth

We say "Gaia did this," or "Gaia did that" not to suggest that Earth is conscious, but to describe the unconscious collaborative efforts of the organisms on Earth that react to Darwinian evolutionary pressure. In the feedback cycle between life and Earth, ice ages and desert are preferred – in balance with the need for vast quantities of life. In Lovelock's words,

Gaia theory provokes a view of the Earth where

1. Life is a planetary-scale phenomenon. On this scale it is near immortal and has no need to reproduce.

2. There can be no partial occupation of a planet by living organisms. It would be as impermanent as half an animal. The presence of sufficient living organisms on a planet is needed for the regulation of the environment. Where there is incomplete occupation, the ineluctable forces of physical and chemical evolution would soon render it uninhabitable.

3. Our interpretation of Darwin's great vision is altered. Gaia draws attention to the fallibility of the concept of adaptation. It is no longer sufficient to say that "organisms better adapted than others are more likely to leave offspring." It is necessary to add that the growth of an organism affects its physical and chemical environment; the evolution of the species and the evolution of the rocks, therefore, are tightly coupled as a single, indivisible process.

4. Theoretical ecology is enlarged. By taking the species and their physical environment together as a single system, we can, for the first time, build ecological models that are mathematically stable and yet include large numbers of competing species. In these models increased diversity among the species leads to better regulation.

We have at last a reason for our instinctive anger over the heedless deletion of species; an answer to those who say it is mere sentimentality. No longer do we have to justify the preservation of the rich variety of species in natural ecosystems...

When the farmer undertakes their work in tilling the soil, they are acting simultaneously as partner, agent and master of Gaia: they change vegetation and ecology.

Weaver and Clements discovered that plants respond to their climate and environment, so much so that the health of plants and plant communities can be understood as indicators of the climate and environment...except when humanity interrupts the natural systems that would have resulted in the most adapted species succeeding by artificially selecting some species for survival and others for deletion in the processes of planting, harvesting, weeding, grazing, constructing, damming and other activities. And yet, in the framework of Gaia, the rapid changes in vegetation in response to climate and environment are as easily explained as humanity's role in accelerating the change even faster, and provide some insight into the evolution of agriculture as a biological phenomenon among humans and other species.

Weaver and Clements put it nicely:

Vegetation is more than the mere grouping of individual plants. It is the result of the interactions of numerous factors. The effects of the plants upon the place in which they live and their influence upon each other are especially significant. When trees develop in an area, they greatly modify conditions for growth by decreasing light and lessening

the force of the wind. Water evaporates less readily from the soil when covered with a mulch of decaying leaves, and the air is more humid under a leafy forest canopy. Sun-loving shrubs and herbs disappear and are replaced by those which thrive in cool, moist, shady places. The trees not only largely determine the kind of plants which grow beneath them but also profoundly influence each other. If densely crowded, they grow tall and straight and usually lose their lower branches as a result of insufficient light. Under such conditions, many species of trees cannot thrive. Where the forest is open, the branches extend more widely and each individual makes a better development. A study of vegetation reveals that it is an organic entity and that, like an organism, each part is interdependent upon every other part.

Vegetation arises from the coming together of individual plants and their interactions upon each other. The latter are brought about by the plants modifying the habitat or place in which they live. The cause it to be wetter or drier; they may increase the richness of the soil and decrease the light. In different ways, they make it a fit or an unfit place for various other kinds of plants to grow.

It is little more to see animals and plants together are a single organic entity, and that that organic entity is itself bonded to the geologic Earth, that the Earth is a single organic entity.

Leavitt Dudley, meteorologist John Aldrich, Dr. John Courter (of the University of Illinois Extension Service), et al. in *Weather Wise Gardening* demonstrate further that the human capacity to influence vegetation for the benefit of themselves and all their fellow creatures in making a place more pleasant and habitable is an essential part of our homemaking. Well planned landscaping creates comfort both inside and out, "each tree and shrub changes the conditions around it. Every alteration, fence, patio or walkway will have some effect on the small-sized climate which surrounds your home," they say. "Our grandparents bettered their living through the use of microclimatic principles because they had to. They couldn't count on central heating and air conditioning to regulate the climates of their homes...The weather-wise gardener is both observant and ingenious. He can make the most of his climate by keeping a close watch on the weather and the individual conditions around his yard. He knows that he cannot make a poor climate perfect, but though modification he can certainly improve it."

Such ingenuity for these magnificently weather-wise gardeners includes use of water features to moderate temperature and light, training plants to grow around the home structure for temperature regulation and weather protection, wind blocks and many other good tricks. But most important of all, both symbolically and practically, the human house becomes for them a functional member of the landscape, allowing some plants to live on a sheltered side, allowing others to be warmed against a sunny wall, or even altering the climate.

Extending the concept further, it is our humanity to construct home-like structures for our plants and animals, too. Whether it is an A-frame trellis for our cucumbers and peas (which works better than a vertical fence) or scaffolding supports for our dwarf trees weighted with fruit, building reflective mirror walls to bring the sun's light around hedges, the construction of heat-storing walls to improve fruit harvests of vines and trees, and even greenhouses – entirely enclosed structures that help the gardener regulate the environment for the benefit of their plants, allowing production even in the winter!

When humanity changes its environment to the benefit of its crops, all species can benefit. Even when the direct impact of a cloche greenhouse (a glass or plastic "bell" that fits over a single transplanted, tender young plant) is upon an individual, the benefit to the entire environment for having healthy, mature vegetation earlier in the season is manifold. Birds bathe in the irrigation water, earthworms thrive under the mulch, snakes find homes in-between walls of human homes.

The gardener who considers the shadows of the sun, the movement of wind and other climatic factors, and applies their learning to make the environment better for life is doing the world a service that no other creature can perform.

Even the ants cannot plant a row of trees to reduce evaporation and increase production, or plant grain in similar but differently angled rows to increase evaporation and reduce risks of disease. What other creature can modify an environment to facilitate the drainage of cold, frosty air? Though ants will build mushroom houses, they cannot fashion glass or plastic for the growth of greens.

Humanity's role in Gaia is a very important one.

The 20% solution: Gaia requires at least 20% of the planetary surface to survive; introduction to why farmers should reserve 20% of their land for wilderness

The experiments of Dr. Lovelock combined with the natural history of this world indicate that Gaia requires 20% of the planetary surface area to survive. This means, of course, that those areas be under strict control by Gaia: that they be wild and unhindered. Sick ecosystems poisoned by herbicide, pesticide, fertilizer, industrial pollutants, etc. perform less well than healthy ones, and agricultural operations are not under strict control by Gaia, able to react to the global needs of species.

One family in a dwelling does not make a village, still less does it constitute a city with a self-sustaining infrastructure. In the same way there is a critical mass of biota needed for planetary homeostasis, the size of which depends mainly upon how much effort is needed to sustain homeostasis and how large are the perturbations likely to take place. Simple models, derived from Daisyworld, suggest that a stable system requires at least 20% cover of the planetary surface if the commoner perturbations are to be withstood. These would be changes in the intensity of sunlight, planetesimal impacts, internal disturbances from the evolution of species that adversely affected the environment, or the exhaustion of some essential resource.

Undertaking trials, we have found that as much as this applies to a global ecology, it applies to a local ecology as well. Generally speaking, so long as we reserved 20% of the ecology in wilderness, pest populations were kept in balance, though this percentage of land depended on the quality (the biodiversity and biodensity) of the natural reservation.

Plant ecology explains rapid changes in vegetation: as environment changes, the vegetation responds, some plants die and others pioneer

By interfacing between the atmosphere and the soil through their stems, plants are essential to the Gaian processes. Yet the importance of leaves to the ecology above the soil is no less profound. Leaves (and stems) provide shelter, nesting, food and fuel for countless creatures. As it is upon the health of roots that the soil survives, it is upon the health of leaves that the surface life survives.

The study of ecology requires an understanding of what plants exist on the surface of a study area. By mapping out the individuals carefully (using quadrats, transects[69] and other coordinate mapping systems), examining the same land every year shows a change of plants. Over many years, the grand migrations of forests can even be observed: plant communities are always moving, and neighborhoods are always changing... until they climax into a forest or a desert.

Doctors Weaver and Clements (*Plant Ecology*, 1929, 1938) undertook just these observations and defined them excellently in their textbook. Using quadrats, transects and tree ring analysis[70], Weaver and Clements demonstrate that "as vegetation develops, the same area becomes successively occupied by different plant communities."

Attributing the succession primarily to the development of humus from bedrock or barren ground, which allows for greater and greater plants. "Within a region, the same or final climax stage results from this series of successive stages whether they start in open water, or solid rock, or on denuded land." Examining the slow drainage of a glacial pond, they see how the plants eagerly pioneer onto the gradually exposed soil and then show how any new land is similarly pioneered when denuded by volcanoes, or how rocks are gradually made into soil by microorganisms like lichen.

What is important to recognize is that when climates change, the species present are not necessarily adapted to the new climate, and this *partially* denudes the land, inducing a new pattern of *gradual* succession. Besides its initial stage of rock, water or denuded land, the climate impacts the climax community as well.

[69] A quadrat is an area that is defined for observation, typically a square. It can be defined any permanent observation post, whether a metal grid mounted on the ground itself, or geosychronized coordinates. Dividing an area into a grid allows accurate pictures to be drawn of the vegetation in that grid every year (or photographs taken), and the precise numerical change in kind, location and number of species to be monitored. Quadrats on grand scales of miles or hundreds of feet are used for larger plants (such as trees), quadrats of a few feet are used for smaller plants. Sometimes a quadrat of a few inches is used in small colonies of sessile microorganisms (like lichen).

Transects are linear quadrats: a line of a defined width is observed through a region. These are excellent for observing the change present between environments, mountainsides or any place where there is a difference between geographic locations. Again, the number, kind and location of species is noted.

Of course, other data is usually taken as well: soil condition, sizes of plants, health of plants, the presence of animals, fungi and microorganisms, etc.

[70] Looking at the rings of trees can identify rainfall and other environmental factors that influence the growth of trees. Averaging the rates of growth over several trees gives better data and reduces the variability of individuals. The frequency of fire, the hardness of winters, and, especially with chemical analysis, all kinds of environmental factors – including the presence of other trees and vegetation – can be learned by looking at tree rings. This is aided through experiments, subjecting plants to various stresses to learn how it changes their rings.

Gaia explains ecological succession into forestation as a response to an unstable environment

The changes Gaia makes to the world are seen through ecological successions and are undertaken by individual organisms as they attempt to improve their immediate environment for their benefit. Succession occurs with the goal of forestation and a highly stable environment.

The environment is inherently unstable: geological plates are shifting, changing albedo significantly. Volcanoes erupt and send dust to the atmosphere. Asteroids slam into the earth and raise dust or water vapor. Immediately following a catastrophic event, the climate has great variability, and the role of the individual in reclaiming the native stability of Earth's biosphere comes into play.

Succession undertaken through individual creatures motivated by selfish interests; life makes humus, humus allows trees

An example can be found in the wild morning glories that colonize dry, salty deserts (usually to the farmer's experience, a mismanaged garden) and other denuded areas. These morning glories shade the ground, improving water retention and cooling the soil enough to allow other plants to germinate. Soon, the lambsquarter and other larger plants can grow and begin to shade the sun loving morning glories. Fighting for their lives, the morning glories attempt to pull down the larger plants they inadvertently allowed, but it is no use. The larger plants already have collected water, desalinated the soil and allowed the first trees to colonize the once sandy desert. The bindweed, now under the shade of great oaks, withers and drops it seeds – which can wait thousands of years until the happy desert returns – amid the roots of the new oak forest. But things have not yet finished! The oaks begin to produce rain and clouds which increase the moisture of the air and soil and they are succeeded by greater and greater trees and the desert is transformed into a thick rainforest (a rainforest is a forest that has become self-reliant upon its moisture needs, condensing enough water to feed itself).

It is always the individual creature – not the species as a whole – that undertakes the changes required for the benefit of the whole planet.

Another example is found in the migration of plants and animals. When seeds are dispersed, some will find their way to the new lands. Some will inevitably survive better than others, and, as more life and more kinds of life enter into the new land, the land becomes better suited to trees. Migration also occurs through roots, and any other kind of reproduction that results in the dispersal of a species. A good example of this in animals is found with squirrels: squirrels ensure the dispersal of their species through territories, and young squirrels are encouraged to find an unoccupied territory.

Life makes humus, and humus allows trees. The intricate symbiosis between trees (and all plants) and soil microorganisms is profound. It is as profound as how the competition of creatures, essential to Darwinian selection, drives this evolution to rainforest. The amount of available water is different for different species, and eventually those which are most suited to the task of making rain clouds – and increasing the available water for other species – thrive... until they die by their success to make way for glorious life forms. Eventually, deserts are conquered in this way: eventually, Gaia does not need deserts to cool the temperature; eventually ice caps form that expose grand expanses

of shallow water – the most biologically rich places on Earth – and these ice caps take the office of the newly greened deserts.

Yet this utopia has not yet happened, and will likely not happen, because the Earth is subjected to many external catastrophes that destabilize the environment.

Gaia's goal: increase the amount and kinds of living creatures to better stabilize the environment that life needs to survive – especially maintaining the water resources required for life; the role of humanity to increase the amount and kinds of life

It is important to note that Gaia is always trying to increase the amount and types of living creatures: the more biodiversity and the more dense that life is, the better life has control over the biosphere, and humanity is key to this biodiversification.

Should something radically alter the earth, such as an asteroid knocking up dust into the atmosphere, it is an asset to the entire world to have a diversity of species: more species, this way, will be naturally adapted to the artificial "winter" that results. There must be those species naturally adapted to the artificial "summer" that results when the feedback cycle overcompensates for the cooling of the atmospheric dust. The sudden swings in temperature and climate that the Earth must undertake as it stabilizes from such a catastrophic event would require many species adapted to many environments: it is necessary, in this world, to have all kinds of creatures, from polar bears to desert mice, deep sea squids and coastal sea otters.

According to Lovelock, "humans and Nature had evolved together to form a system that sustained a rich diversity of species...Gaia emphasizes most the significance of the individual organism. It is always from the action of individuals [human and otherwise] that powerful local, regional, and global systems evolve. When the activity of an organism favors the environment as well as the organism itself, then its spread will be assisted; eventually the organism and the environmental change associated with it will become global in extent. The reverse is also true, and any species that adversely affects the environment is doomed."

As the Sun has continued to warm, there is less and less need for greenhouse gasses. The Earth is too warm these days and, though Carbon dioxide levels in the atmosphere have decreased almost to nothing, our planet continues to be warmed by the growing sun, inviting desertification, the herald of ice! A new Ice Age is poised to welcome a day without Carbon dioxide, one dominated by plants that require less or no Carbon dioxide to survive (such as the grasses, which evolved, timely enough, just as this new Carbon crisis began and already have developed representative species in tree and shrub forms).

And yet humanity is now releasing vast quantities of Carbon dioxide and the temperature of the Earth is responding appropriately. The golden years of the coming ice, when life would flourish in its happiest condition, are postponed as deserts grow out of proportion to their increased need.

Carbon dioxide was released as humanity has cleared the great forests of Europe, the Americas and Africa, leaving fewer plants to reduce the atmospheric Carbon; Carbon dioxide was released as humanity began to burn fossil fuels in the 19th Century, causing an acid rain that destroyed the ability of the soil and ocean to reduce atmospheric Carbon. But besides the Carbon release, humanity actively reduces both the kinds and number of living creatures through poor methods of agriculture.

Competition the best defense against weeds and pests

As discussed by Carson, competition is the best defense against weeds and pests. The phenomenon was also explored in depth by Weaver and Clements. "The coming together of plants in the processes of migration, ecesis, and aggregation results in competition. When a plant is carried into a group of other plants or is surrounded by its growing offspring, the struggle which results between the individuals is competition. This movement of a plant or a group of plants from one area into another and establishment in the new home is termed invasion."

For competition to be effective, that is to say, if invasion is to become possible, free entry and exit must be provided to the creatures of the field. When this occurs, a decrease in the amount of water, nutrients, light and other resources results and pressures each member of the ecosystem into a balanced structure, wherein some species are dominant and in balance with the natural resources.

The year after we were spared from the potato beetle and our neighbors were not, there was an extraordinary number of aphids. While at first their numbers grew so powerful in our field that our plants appeared at risk, we remained patient and before serious damage had occurred, the population of predatory ladybugs and other creatures increased sufficiently to bring the aphids under control. As the populations of both predator and prey were reduced (the predators were running short of aphids), some ants came and domesticated the aphids for dairy production (ants will milk their aphids and graze them on pastures, carrying them from place to place, defending them against predators, and even bringing them underground in the winter).

Yet we were still not worried. Ants are good aphidherders. They never let their aphids exhaust a plant or significantly harm a plant, either. Whereas the aphids would have remained on a plant until its death, the ants moved the aphids about to ensure maximum "milk" production. More than any other predator, the ants brought harmony to the field. We are always glad to see the ants when we are working: they hunt, they farm, they ranch and bring harmony wherever they go.

Weaver and Clements explain that invasion is a process of succession, and while invasion naturally occurs when resources are stressed and there is room for new species to enter into an arena, sometimes species cause that pressure to capture territory. "Properly speaking, competition exists only when plants meet each other on more or less equal terms. There is no competition between a host plant and the parasite upon it, but two or more parasites upon the same host may compete with each other...a dominant does not compete with a secondary herb of the forest floor, e.g., an oak with jack-in-the-pulpit. The latter has adapted itself to the conditions made by the trees and is in no sense a competitor of the oak. Indeed, as in many shade plants, it may be a beneficiary and quite unable to grow in the area except for shade, humus, etc., afforded by the oaks. The case is different, however, when the seedlings of the tree find themselves alongside of the herbs drawing upon the same supply of water and light. They meet upon more or less equal terms, and the process is essentially similar to the competition between seedlings alone on the one hand or herbs on the other...naturally, it is not at all rare that the seedling tree succumbs. When it persists, it gains an increasing advantage each succeeding year and the time comes when competition between tree and herb is replaced by dominance and subordination."

Too much warfare between species and they all suffer: like domestic crops sown too tightly, they fail to reach their potential size and fruitfulness. Leaves grow smaller, roots shorter, and in all ways the plant tries to make do with less. When weeds invade the crops, the crops yield less.

Tullian tillage, however, defends the crops against the invaders much as ants defend their domesticated plants against invaders: by killing the invaders. But, though invasion is not to be

worried for, when this occurs a loss of biodiversity is a worry: the invaders will necessarily increase the biodiversity and competition among the animals that would eat the crops.

There is a need to defend crops against competition: Weaver and Clements demonstrate that oat plants under competition in rows 6 inches apart have roots and tops approximately 10 times smaller than oats grown without competition.

Destroying weeds destroys friendly predators that protect crops, and while it seems a difficult balance between protecting against invasion and defending the crops against pests by biodiversity, it is not. Dr. Lovelock has already undertaken important work towards understanding the thresholds of wilderness in an ecology's self-regulation.

Desertification of the United States and the World

The deserts are growing rapidly these days in response to global warming conditions. In 1981, David Sheridan of the Council on Environmental Quality of the United States government, described in his report *Desertification of the United States* a dangerous situation for humans. Not only was the environment naturally desertifying, but human action was accelerating and expanding deserts unnecessarily.

Sheridan puts it simply. "Desertification in the United States has some very far-ranging implications in terms of the nation's food and energy supplies, balance of payments, and environment. It is an affliction that saps an arid land's ability to support life. Its major symptoms are: declining groundwater tables, salinization of topsoil and water, reduction of surface waters, unnaturally high soil erosion, and desolation of native vegetation."

Examining the growth of the four American deserts (the Mojave, Sonora, Great Basin and Chihuahua), he discovered that "desertification breaks out, usually at times of drought stress, in areas of naturally vulnerable land subject to pressures of land use...it is generally incorrect to envision the process as an advance of the desert frontier engulfing useable land on its perimeter: the advancing sand dune is in fact a very special and localized case. Desertification, as a patchy destruction that may be far removed from any nebulous front line, is a more subtle and insidious process."

Contributing to this is the mining of groundwater (pumping more water out of the groundwater supplies than nature puts back in), damming rivers to make water available on demand and transporting water long distances, overgrazing and salinization of cropland due to poor irrigation techniques.

"There is not technical mystery to solving the age-old irrigation problem of salinization," reports Sheridan, "The solution is quite clear – drain off the excess groundwater. First the irrigator needs to install an on-farm drainage system to collect the perched saline groundwater...next, the irrigator needs to dispose of the drained water," usually through wells or ditches into human-made marshes or lakes.

Tullian tillage will also act against salinization, both by reducing or eliminating the need for irrigation and by helping the soil detoxify the salts.

Sheridan includes in his report shocking testimony from Jack Johnson, then Director of the Office of Arid Land Studies at the University of Arizona: "I don't care if you're talking about Arizona or if you are talking about sub-Saharan Africa...there are very, very few arid lands today that are being grazed within their carrying capacity."

While Sheridan recommends intensifying the already-sufficient controls against overgrazing on government lands, it would do little to overcome overgrazing on private lands: the local governments responsible for that land policy are unlikely to enact such conservation measures, as it would upset their electorate who, selfish in their short-term interests, would prefer to overgraze today and have nothing to graze tomorrow. Similarly, controls against off-road driving, which result in dangerous drainage conditions that increase erosion considerably, are unlikely to be made or enforced.

And here is an insight into the problem: while it would be natural, and potentially logical, for herders to overgraze lands which are not their own and belong to a Federal government, it is unnatural and illogical that they would decimate their own inheritance. There are other motivational forces at work.

The government provides relief to farmers and ranchers who suffer from the desertification, encouraging the behavior by providing them with the revenues they would have obtained had desertification not occurred. Banks continue to loan operating funds to farmers, who are able to pay the banks with the relief money. While there are some government conservation programs too, Sheridan concludes that, evidently, they are insufficient.

Sheridan says that mining practices that damage the water systems of threatened lands, deforestation and unsustainable lumbering, military uses and exploding urban populations are also encouraging desertification. Sheridan also points to the inability of the Federal (and other inter-regional) governments to regulate water use and land use as also to blame.

The lack of demand for crops that grow easily in deserts (even delicious fruits such as the date or prickly pear, or vegetables such as lambsquarter and amaranth, or any of the numerous desert grains) encourage farmers to not grow the crops that would stave off or reduce desertification.

Yet, as much as the public's government and market demands are to blame, ultimately, it is the farmer and the rancher who must maintain their lands as an inheritance to the next generation, it is the farmer and the rancher who must calculate, against the short-term gains of overusing and abusing their lands, the long-term profits of sustainable agriculture.

It is the farmer who is failing in their partnership and agency with Gaia as they undertake an abusive mastery of Her; it is the farmer who fails their children and the entire world when, in the fits of an insane and corruptive greed, they sell their inheritance too cheaply.

Succession occurs as soil is built or destroyed. Humanity can build or destroy soil through agriculture. Upon soil the leaves and fruits of vegetation grows, the fate of the planet is balanced.

Farmers must turn to Tullian methods to adapt to changing climate and work with Gaia to stabilize the climate

Even Dr. Lovelock, with his celebrated calculations, cannot predict what humanity will do against these crises. The easily predictable chemical reactions of species is muddled and confused by human consciousness and irrationality: the oceans are dying from strange new pollutants that microorganisms are unfit to cope with, excessive quantities of Carbon dioxide are being emitted by human sources, and there is a new dynamic now between forests and grasslands as humans cut down trees to expand grasslands – not long ago, the trees overshadowed the grasses, and succeeded them!

It is possible that, instead of tipping into another ice age, the oceans will warm to the point of dying and a mat of bacteria will produce enough hydrogen sulfide to kill much of the remaining

life on Earth. It is also possible that humans will make the necessary decisions to avoid such a fate. Faced with the cataclysmic, it is reasonable that farmers should turn to a system of agriculture that not only allows them to cope with a crazy new climate, but one that actively works with Gaia to stabilize it.

Tullian agriculture feeds the soil magnificently. It increases the kinds and numbers of living creatures beneath the soil and, with the improvements lent by modern science, increases the kinds and numbers of living creatures above the soil as well. It reclaims the deserts, it cleans up pollution. It empowers small farmers to undertake agriculture, leading to yet more biodiversity as different farmers undertake different crops. It promotes the microorganisms that sequester carbon in the soil, cooling the planet. It increases soil moisture to green the deserts with plants that will even more actively entomb carbon in the soil.

While the interaction between Tullian agriculture and the environment is discussed throughout the book, the fundamental introduction to the theory of the relationship here presented serves to demonstrate that the farmer who secures for their children a better inheritance through the adoption of Tullian methods also secures for the entire planet a better future.

RESERVATIONS

Why the grasshoppers and deer did not eat the beans: they had food, and did not want to eat their home; leaves provide shelter and food to many species, but not always simultaneously

Leaves provide essential shelter and food to many species, but not always simultaneously.

One year there were a tremendous number of grasshoppers. On neighboring fields, they devoured the plants, but on ours they sat lazy in the sun on top of our beans and did not eat them. There were grasshoppers on each plant, and not a bite of damage. The previous year, the deer were (seemingly as) numerous and had destroyed many fields – except ours. Several years previous to that, the Colorado potato beetle had destroyed all the potatoes in the neighborhood except ours.

Our neighbors knew we used not poisons, and, despite scientific explanations to how we were consistently spared the loss from predation, considered us to be extraordinarily and only lucky.

Yet luck aside (though no farmer would willingly put aside their luck), we had undertaken to prevent disaster by providing better food than our crops to the grasshoppers and the deer; they used our crops only as shelter or not at all.

Experiments with snails demonstrating herbicide necessitates pesticide; snails eat domestic crops for lack of other options, and do not prefer them

Would pests, if given foods they prefer, leave crops alone? Would such a system be sustainable, or would the farmer only increase the number of pests beyond their natural carrying capacity?

In 1997, the thought occurred to us after seeing that some animal "pests" ate our weeds that they had definite food preferences: what if the weeds were dead? The "pests" would then, likely, eat our crops, as they ate the crops of our neighbors who killed whatever weeds grew in their fields without reservation.

We sought to undertake an experiment to learn whether snails could be raised in a greenhouse actively growing vegetables to find the answer to our question. We chose snails because they were easy to observe, were known garden pests and could be easily contained in an experimental plot.

We found that so long as snails have their favorite foods (weeds), they would leave domestic crops alone.

We began by testing our snails to see what foods they preferred by presenting to them repeatedly a choice between two kinds of food. By alternating in a choice of more than a dozen foods, we learned that our snails preferred weeds to lettuce and least preferred radishes and carrots.

Because we could obtain no weed seed at that time of year, we planted lettuce, radishes and carrots in our greenhouse, and penned the snails in among the plants.

The trial plots were 1 square foot each, and were filled with 5 snails each. The plots were 1 foot deep. For the vegetables, we used soil we knew to be depleted of nitrogen, phosphorous and potassium, and which had been sterilized.

The snails never ate the radishes or the carrots in 5 trials and, at the end of the trials, the soil, which was 1 foot deep, was highly fertilized top to bottom.

The trials lasted 4 months each, long enough for the snails to mature to a harvestable size (the snails were already more than half-grown when they were placed in their experimental pens). During the course of the experiments, the 5 trials consumed 3 heads of lettuce, each valued at $0.50, though it us more accurate to discount the price of the heads because the lettuce in this trial was substituting the weeds (for which we could obtain no seeds at that time of year), which (in our trials) the snails preferred even more than lettuce. Besides, these heads were "scrap" heads and were "wastes."

The 5 square feet of tests yielded a total of 21 healthy radishes (we had planted 22, but one was crushed by a snail who had managed to climb to the ceiling of our enclosed pen and fall directly on top of it) and 23 healthy baby carrots, or roughly 2.75 bunches total. With each bunch being valued at about $1, the plots yielded $2.75 of produce at a cost of $0 in pest control, $0 in fertilizer and $0 herbicide: profits were $0.55 per foot, or $23,958 per acre before aisles were considered. When the cost of the 3 baby heads of lettuce are considered at full value, at $0.30 per foot, the profit per acre is reduced to $10,890, or $0.25 per foot.

On top of this, it yielded 25 snails, each valued at $0.25 each, or $6.25 total, about $1.25 per foot – more than 5 times the adjusted price of the entire field.

It was as shocking as if sheep had been penned in a hay pasture, and the hay still could be cut as much as had they been fenced out!

While not every farmer will be selling the snails in their garden, or any of the other animal guests there, it suffices to demonstrate that the snails did not actually decrease crop production significantly or at all and, even if the farmer were to provide them foods to eat, the cost of doing so is overcompensated by the savings from reduced predation.

Also, it serves to demonstrate that when the favorite foods of snails are removed from a garden (i.e. weeds), they turn to eating the farmer's crops.

Subsequent trials demonstrated that when the choice was not as stark between the snails' favorite and least favorite, some crops did get eaten, but by never more than the typical cost of herbicide, pesticide and fertilizer would have been overcompensated. Besides, outside of a greenhouse, the snails have the ability to wander to find more of their favorite foods (as evidenced by how they do not ravage our crops), and in a greenhouse, the farmer can choose to include the favorite foods of the snails.

We then observed our valuable pests in a more natural setting, and in an outdoor garden. We concluded that the use of herbicide results in a necessity for pesticide as those animals which depended on the weeds will become enemies to the farmer who stole their food and that if weeds, which are naturally preferred by most pests, are allowed to grow in the field, and if natural predators are encouraged, the natural carrying capacity of the pests is not altered by the presence of their preferred foods and may in fact be decreased.

Objection to the results: the number of snails would increase if not controlled by human actions, that chemical pesticide would be cheaper and more effective in the long-term; answered by demonstration that predators would increase to control snail population, and that human pesticides are generally ineffective and more costly

An objection raised at the time by an observer of our snail experiment was that the cost of lettuce, or the quantity of weeds required, would increase over time as the population of snails grew whereas the cost of a good pesticide would remain constant and effective.

We answer that while this might be true in a greenhouse, in an open field, the predators of snails would also increase in number and keep the snail population in balance with their food supply. Thus, the farmer needs only to provide enough food or let sufficient quantities of weeds grow to prevent the snails from hungering for the domestic plants.

Besides, the ability of pests to adapt to pesticides is extraordinary: as the scientists such as Masanobu Fukuoka, Rachel Carson and others have demonstrated, and as the practical experience of farmers will agree, pesticides (and herbicides), as a rule, breed resistant pests by selecting those which would survive and cost more than they return.

Pesticides and herbicides do not reduce crop loss enough to compensate their cost

Pesticide and herbicide chemicals are very expensive. While costs vary by brand it is possible to compare an average pesticide cost against conserving enough land to feed pests and provide habitat for their predators. The University of California in their publication *Establishment and Production Costs, Valencia Oranges, Coachella Valley, Riverside County, 1998* by Etaferahu Takele and Peggy Mauk (http://coststudies.ucdavis.edu/ files/coachvaloranges.pdf) reports that an orange orchard will yield 600 boxes of oranges per acre. With each box weighing about 50 pounds, this results in 30,000 pounds of oranges. This comes at many costs, but considering herbicide and pesticide costs only, including materials, labor, fuel, lube and repair, it amounts to $245 per acre, nearly 26% of the total cultural costs per acre. If the farmer earns, as Takele and Mauk suggest, $3,024 per acre, 8.10% of their income is spent on herbicide and pesticide alone!

The University of Florida reports slightly higher numbers *in The Dynamics and Implications of Recent Increases in Citrus Production Costs* by Ronald P. Muraro and Robert A. Morris (http://edis.ifas.ufl.edu/fe793). Their study, representing the years 2002 through 2008 show an increase in the cost of these chemicals. By 2003, pesticide and herbicide costs amounted to 41.30% of cultural costs; in 2008, pesticide and herbicide costs amounted to 30.30% of cultural costs.

If these expensive chemicals actually worked, it might be worth the expense. However, the Food and Agriculture Organization of the United Nations reports in their *Crop Production in the*

Context of Agricultural Development (http://www.fao.org/WAIRDOCS/TAC/Y4847E/ y4847e05.htm), "On a global level pest were reported to take a significant part of the harvest. A comprehensive study by Oerke et al. (1994; 1999) analyzing a huge volume of field trial data found that crop losses range from 25 to over 50% depending on the crop (Figure 1). While the productivity impacts of such high crop losses are significant, it is disturbing that over the past three to four decades, crop losses in all major crops have increased in relative terms. These data are widely cited also in CGIAR documents. For example, an IFPRI report on *Pest Management and Food Production* (Yudelman et al. 1998) reproduced these data and underlined the seriousness of pests as a major constraint to increase food production. To complement the analysis a closer look at the corresponding results for rice emphasizes the serious implications of this situation. ***The amount of yield that is lost to pests, among which weeds are the major one, is more than the amount that can be saved by using pesticides.*** [Our italics – A.B. & M.C.] On average overall effectiveness of pest control is only 33% and is lowest for insect pests."

Rice is not alone in being unsuited for chemical protection. Weeds and animals – especially insects – adapt rapidly to chemical pressure. As Rachel Carson and Masanobu Fukuoka have shown, the chemicals applied to pests kill or harm those creatures which would have been eating or destroying the pests in the first place better than they kill the pests themselves. This results in even greater numbers of pests.

Clearly the answer does not lie in killing predators of the farmer's enemies. An enemy of your enemy is your friend.

The cost of chemicals is directly related to the cost of their manufacture and their effectiveness. But the cost of nature reservations is related to the opportunity cost of the land now devoted to weeds.

Thus, should the farmer dedicate even 20% of their land in a reservation of nature for the promotion of friendly predators – every 5th bed and aisle, or an equivalent area – they are spending 20% of their revenues, considerably more than the 9% they would have spent on chemicals.

Yet when the farmer who would spend 20% of their revenues on reservations and tillage goes to harvest their crop they find they have lost nothing – or nearly so. The tillage prescribed by Tull is a more effective herbicide than any chemical and the predators in the reserves defended what few pests sought out the crops against the shelter and food of the reservation. Thus, when a farmer spends 9% of their income on chemicals and still loses 25%-50% of their crop, they should have spent 20% of their income on reservations and tillage and kept the remainder.

Pesticides and herbicides reduce the soil's fertility and autofertility

As previously discussed in the chapter on roots, soil and compost, the soil is naturally self-fertilizing through the actions of microorganisms. Unsurprisingly, applying toxic herbicide and pesticide onto a field damages or kills these microorganisms as well. Yet closely allied to these microorganisms are microscopic mites and insects, and even larger organisms such as worms and more standard-sized insects.

While humus can detoxify many of these poisons before much harm is caused to the microorganisms, there may be insufficient humus to cope with the toxins. The pesticides and herbicides destroy the humus, and prevent its remanufacture.

Of course, a simple solution is to not use herbicides and pesticides, to reserve natural areas with their wealth of biodiversity, and to till as Tull prescribes to generate more humus. This simple

solution is not only less costly than herbicides and pesticides, it is more effective at pest control. In this way we have successfully reclaimed highly polluted soils that were toxified to the point that nothing would grow on them.

The best way to control pest populations – whether animal, plant, fungi, or microorganic – is through the competition of a biodiverse and biodense environment.

Pesticides and herbicides increase the need for pesticides and herbicides, sometimes increasing pest populations; natural controls are best, and are best obtained through natural reservations

Natural reservations provide to the farmer an effective form of pest control by harboring those friendly organisms that defend crops best. The use of herbicide and pesticide has, in experiments and experience, increased pest problems.

Economy of a system of reservations and tillage may be shocking, but is true

As shocking as it is true that tillage increases fertility, as shocking as it is true that aisles with no crops in them increase total field production, it is shocking but true that promoting predators through natural reservations increases crop yields. We have undertaken extensive trials, and found – on our lands – that 20% reservation was ideal: it was more efficient than alternative methods and it was a great deal safer for us and our neighbors.

In different ecologies, the amount required for reservation will vary – it is based on the natural biodensity and biodiversity of the area. As Doctors Lovelock, Weaver and Clements show, it is the density and diversity of life that allows a stability of vegetation – and when the vegetation is crop land, this stability results in long-term sustainable profitability.

Thus, some farmers will need to retain 20% in reservation, others can get by with much less (in one test, we obtained good results when less than 5% was reserved). Other farmers will need to reserve much more.

But to reduce the total amount required for reservation requires increasing the habitat for life in other ways, such as through polycultural intercropping methods, orchard and hedge integration, and wilderness reclamation. But nothing can replace the great utility of weeds.

Be assured, the farmer who would lay down their chemicals will receive peace in their endless, dubious war against pests. The farmer who willingly surrenders some of their land to nature is allowed to hold the remainder in peace. It is the debt we owe to Gaia, who we represent as agent, partner and master.

Other costs to chemical herbicide and pesticide I: reasons by which biodiversity and biodensity decrease crop loss, and decreasing biodiversity and biodensity increases crop loss, and the dangerous bioaccumulation of poisons, why pesticide and herbicide increase pest populations

It at first seems insane to apply a poison that kills the friendly predator species that eat pests better than the pests themselves, but when it is learned that the poison harms people as well, all doubt vanishes and the monstrosity of the act is laid bare. Yet so many farmers burn the village to cook their pig!

Rachel Carson, a marine biologist with the US Fish and Wildlife Service, and the founder of the environmentalism movement, was particularly outraged at the senseless destruction wrought by pesticides and herbicides, though she herself did not object to them in principle if used limitedly:

The whole process of spraying seems caught up in an endless spiral. Since DDT was released for civilian use, a process of escalation has been going on in which ever more toxic materials must be found. This has happened because insects, in a triumphant vindication of Darwin's principle of the survival of the fittest, have evolved super races immune to the particular insecticide used, hence a deadlier one has always to be developed – and then a deadlier one after that. It has happened also because...destructive insects often undergo a "flareback," or resurgence, after spraying, in numbers greater than before. Thus the chemical war is never won, and all life is caught in its violent crossfire...

...Under primitive agricultural conditions the farmer had few insect problems. These arose with the intensification of agriculture – the devotion of immense areas to a single crop. Such a system set the stage for explosive increases in specific insect populations. Single crop farming does not take advantage of the principles by which nature works...Nature has introduced great variety into the landscape, but man has displayed a passion for simplifying it. Thus he undoes the built-in checks and balances by which nature holds the species within bounds...

[But, observe in the next extract, an example of what happened when people got annoyed at gnats and poisoned the lake that the gnats lived at. The farmer not only undoes the built-in checks and balances by changing the environment to be less diverse, the farmer also targets those species responsible for checking pests for destruction by applying chemicals that the pests easily adapt to and that predators do not. –A.B. & M.C.]

The poison is picked up by the smallest organisms, concentrated and passed on to the larger predators. Plankton organisms were found to contain about 5 parts per million of the insecticide (about 25 times the maximum concentration ever reached in the water itself); plant-eating fishes had built up accumulations ranging from 40 to 300 parts per million, carnivorous species stored the most of all. One, a brown bullhead, had the astounding concentration of 2500 parts per million. It was a house-that-Jack built sequence, in which the large carnivores had eaten the smaller carnivores, that had eaten the herbivores, that had eaten the plankton, that had absorbed the poison from the water.

Even more extraordinary discoveries were made later. No trace of DDD could be found in the water shortly after the last application of the chemical. But the poison had not really left the lake; it had merely gone into the fabric of life the lake supports. Twenty-three months after the chemical treatment had ceased, the plankton still contained as much as 5.3 parts per million. In that interval of nearly two years, successive crops of plankton had flowered and faded away, but the poison, although no longer present in the water, had somehow passed from generation to generation. And it lived on in the animal life of the lake as well. All fish, birds and frogs still contained DDD. Among these living carriers were fish that had hatched nine months after the last DDD application. Grebes, and California gulls that had built up concentrations of more than 2000 parts per million. Meanwhile the nesting colonies of the grebes dwindled – from more than 1000 pairs before the insecticide treatment to 30 pairs in 1960. And even the thirty seem to have nested in vain, for no young grebes have been observed on the lake since the last DDD application...

[The interconnectedness of life, bound by the circulation of matter through "food chains," seen so clearly when poison is introduced to the system, also demonstrates hope for the farmer who would control pests. –A.B. & M.C.]

...In some quarters nowadays it is fashionable to dismiss the balance of nature as a state of affairs that prevailed in an earlier, simpler world – a state that has now been so thoroughly upset that we might as well forget it...

...Two critically important facts have been overlooked in designing the modern insect control programs. The first is that the really effective control of insects is that applied by nature, not by man. Populations are kept in check by

something the ecologists call the resistance of the environment, and this has been so since the first life was created. The amount of food available, conditions of weather and climate, the presence of competing or predatory species, all are critically important. "The greatest single factor in preventing insects from overwhelming the rest of the world is the internecine warfare which they carry out among themselves," said the entomologist Robert Metcalf. Yet most of the chemicals now used kill all insects, our friends and enemies alike...

[And they harm our friends and ourselves more than our enemies! –A.B. & M.C.]

The second neglected fact is the truly explosive power of a species to reproduce once the resistance of the environment has been weakened...we see the miracle of nature's control at work when the cod move through winter seas to their spawning grounds, where each female deposits several millions of eggs. The sea does not become a solid mass of cod as it would surely do if all the progeny of all the cod were to survive. The checks that exist in nature are such that out of the millions of young produced by each pair only enough, on the average, survive to adult hood to replace the parent fish...

...the dire results of upsetting nature's own arrangements are well known to students of animal populations. The stockman's zeal for eliminating coyote has resulted in plagues of field mice, which the coyote formerly controlled. The oft repeated story of the Kaibab deer in Arizona is another case in point. At one time the deer population was in equilibrium with its environment. A number of predators – wolves, pumas, and coyotes – prevented the deer from outrunning their food supply. Then a campaign was begun to "conserve" the deer by killing off their enemies. Once the predators were gone, the deer increased prodigiously and soon there was not enough food for them. The browse line on the trees went higher and higher as they sought food, and in time many more deer were dying of starvation than had formerly been killed by predators. The whole environment, moreover, was damaged by their desperate efforts to find food.

The predatory insects of field and forests play the same role as the wolves and coyotes of the Kaibab. Kill them off and the population of the prey insect surges upward...the trouble is that we are seldom aware of the protection afforded by natural enemies until it fails. Most of us walk unseeing through the world, unaware alike of its beauties, its wonders, and the strange and sometimes terrible intensity of the lives that are being lived about us. So it is that the activities of the insect predators and parasites are known to few...

[Just because a farmer does not see the predators at work does not mean they are not working! But this is no less of a mistake than the farmer not observing, time and time again, that insects and other pests adapt, through Darwinian selection, to the poisons applied to them: selecting those that are most resistant leads to general resistance. Of course, sometimes they are not affected at all! –A.B. & M.C.]

Sometimes the result of chemical spraying has been a tremendous upsurge of the very insect the spraying was intended to control, as when blackflies in Ontario became 17 times more abundant after spraying than they had been before. Or when in England an enormous outbreak of the cabbage aphid – an outbreak that had no parallel on record – followed spraying with one of the organic phosphorus chemicals.

At other times spraying, while reasonably effective against the target insect, has let loose a whole Pandora's box of destructive pests that had never previously been abundant enough to cause trouble. The spider mite, for example, has become practically a worldwide pest as DDT and other insecticides have killed off its enemies...When in 1956 the United States Forest Service sprayed some 885,000 acres of forested lands with DDT, the intention was to control the spruce budworm, but the following summer it was discovered that a problem worse than the budworm damage had been created...It was evident that the summer of 1957 had brought the most extensive and spectacular infestation of spider mites in history. Almost all of the sprayed area was affected. Nowhere else was the damage evident. Searching for

precedents, the foresters could remember scourges of spider mites, though less dramatic than this one. There had been similar trouble along the Madison River in Yellowstone Park in 1929, in Colorado 20 years later, and then in New Mexico in 1956. Each of these outbreaks had followed forest spraying with insecticides. (The 1929 spraying, occurring before the DDT era, had employed lead arsenate.)

Why does the spider mite appear to thrive on insecticides? Because the obvious fact that it is relatively insensitive to them, there seem to be two other reasons. In nature it is kept in check by various predators...all of them extremely sensitive to insecticides...[and] *population pressure within the spider mite colonies. An undisturbed colony of mites is a densely settled community, huddled under a protective webbing for concealment from its enemies. When sprayed, the colonies disperse as the mites, irritated though not killed by the chemicals, scatter out in search of places where they will not be disturbed. In doing so, they find a far greater abundance of space and food than was available in the former colonies. Their enemies are now dead so there is no need for the mites to spend their energy in secreting protective webbing. Instead, they pour all their energies into producing more mites. It is not uncommon for their egg production to be increased threefold – all through the beneficent effect of insecticides...*

[When a pest is susceptible to spraying, the farmer sometimes trades one pest for another – A.B. & M.C.]

...In the apple orchards of Nova Scotia in the late 1940's the worst infestations of the codling moth (cause of "wormy apples") were in the orchards regularly sprayed. In unsprayed orchards the moths were not abundant enough to cause real trouble...DDT promised to "obliterate the nightmare" of codling moth outbreaks. What actually resulted from its use was an unprecedented scourge of mites...

...Darwin himself could scarcely have found a better example of the operation of natural selection than is provided by the way the mechanism of resistance operates. Out of an original population, the members of which vary greatly in qualities of structure, behavior, or physiology, it is the "tough" insects that survive chemical attack. Spraying kills off the weaklings. The only survivors are insects that have some inherent quality that allows them to escape harm. These are the parents of the new generation, which, by simple inheritance, possesses all the qualities of "toughness" inherent in its forebears. Inevitably, It follows that intensive spraying with powerful chemicals only makes worse the problem it is designed to solve. After a few generations, instead of a mixed population of strong and weak insects, there results a population consisting entirely of tough, resistant strains.

—Rachel Carson, *Silent Spring* (1962)

Structural, behavioral and other inherited adaptations aid the insects as they adapt. Because they reproduce faster than their predators, they have an adaptational advantage over their predators. Some insects can adapt within a year!

Carson references the entomologist GC Ullyett, "We must change our philosophy, abandon our attitude of human superiority and admit that in many cases in natural environments we find ways and means of limiting populations of organisms in a more economical way than we can do it ourselves."

The chemicals remain in the soil and water long enough to damage the people who use the food grown on it to feed their children, who use the cotton and wool grown from it to warm their skin against the treeless, dusty wind of a lifeless desert.

Other costs to chemical herbicide and pesticide II: many weeds are useful, valuable, nutritious foods

Many weeds are edible and nutritious, and quite delicious traditional foods. The farmer who would kill them removes from their field a valuable resource. In example, lambsquarter, similar in flavor to spinach, is a weed that is greatly detested. It yields a valuable vegetable (which can sell for many times more per pound than regular spinach, and his higher in calcium as well) and grain (also known as "black quinoa"). Many weeds have medicinal properties as well.

We have earned good profits by harvesting these weeds and, if we are not to exterminate them from our fields, must take steps to domesticate them by saving and planting their seeds for next year. Purslane and dandelion both once were a bane to many farmers. But now, because both are highly nutritious and delicious plants, demand for it has increased in recent years so much that they are beginning to become commonly cultivated vegetables, with seeds for sale by multiple vendors in multiple varieties. Breeding is being undertaken to improve yields.

The demand for weeds is limited by the consumer's willingness to try new foods and price; most edible plants are palatable in some way or another, and many have medicinal properties. The supreme efforts of those early farmers who introduced wheat to Europe are vindicated today by the dominance of wheat over oats.

In Anatolia, the people grow wheat and rye together in the same field, not so much by choice as by tolerance (Kuster, *The Cambridge World History of Food*, 2000). The rye and the wheat get mixed up in the harvest, and a blend of seeds gets planted the following year. Yet by this polyculture, the Arabs enjoy food every year, for when conditions fail to be good for wheat, the rye does well, and when the rye fails the wheat does well.

Natural areas are comprised entirely of weeds, and yet not one species out competes another. Flies and mosquitoes – both essential pollinators – are considered pests and killed alongside the bees, moths and butterflies, which are also essential pollinators. The insanity of killing a species when every species is interconnected for the benefit of the farm is needless.

Other costs to chemical herbicide and pesticide III: rivers, oceans and mariculturalists suffer from runoff

The herbicides and pesticides do not only remain in one place and cause extensive and long term damage to the environment: they are carried by water to the rivers and the seas, causing terrific horror along the way and upon arrival. The widespread death of the oceans reported by the Oceanographer Jacques Cousteau is due, in no small part, to the pollution of herbicides and pesticides. With the death of the oceans comes the death of the land; in the oceans live the majority of life forms on Earth, and it is Gaia's greatest strength. The damage to mariculturalists, collateral as it is, is not to be underestimated, either.

Other costs to chemical herbicide and pesticide IV: other pollutants to be considered

While not strictly belonging to this subject, the pollutants of other industrial processes interact with the herbicides and pesticides of agricultural industry to produce new toxins. When suspended in water and exposed to sunlight, the chemicals can mix together and create new, even more dangerous chemicals in a way that is uncontrollable.

Considerations in making reservations

In providing food and shelter for all the living organisms on the farm, it is important to consider their migratory patterns and territorial behavior. While it is convenient to the farmer to maintain reservations in beds and aisles, this may or may not be convenient to the wildlife. Understanding the needs of the wildlife requires understanding what species are present, their general needs as a species, and the needs of individual members.

For example, we once hosted a den of foxes, and knew that they would require no additional alterations to our field: they enjoy hunting along our aisles. However, when it became apparent that there were to be kits, we ensured that their den had a wide (20 foot) natural reservation around it to reduce any risk of the young kits (or their parents) being disturbed. We enjoy foxes: they are good defenders of our crops, and well worth the bed space because they were so rare where we rented land then.

The UNFAO recommends shelter plants for farmed snails to be centrally located for the convenience of the snails. This is true, too, for wild animals. Putting shelters for them in central locations allows them to better access your field. Putting shelters for carnivorous protectors far off to one corner of a field does not do much for the far corner unless the field is very small. Putting the shelter plants for snails in a corner does not let them graze well. On one of the fields we rented, we condensed our reservation into a single patch in the middle, and a path to the nearby creek. The patch became a favorite haunt of foxes and coyotes, who were able to hunt mercilessly from its blinds. Skunks, too, came to enjoy our patch greatly, and when, one year, a mother skunk and her kits came to frequent it, we knew we would have many fewer pests.

Make sure that there are sheltered paths from the reservations to the best hunting grounds (your fields). Ensure that critical resources (such as water, creeks, etc.) are reserved and accessible – or provide water for the wild creatures.

To know just how big your reservation ought to be, consider how fast and far the animals travel. If an animal can only travel a few dozen feet in a day and must return home at night, the reservation ought to be very small. However, you are trying hardest to attract those animals who range far over your fields, you'll want to have a big reservation. These larger carnivores, the foxes, the coyotes, the hawks, the owls, the snakes, etc. require enough room to make their homes and enjoy some security.

There is a difference between the hunting territory and the home territory of a predator: the home territory is the area required to establish their home in. For our family of foxes, they appreciated an expanded home territory when they had kits. Some animals do not need a home territory and are nomadic.

Examining how far these predators range in your area and how much room and kinds of shelter they require to make their homes allows you to be a better host. It pays to be familiar with your garden's helpers, and so we have included a chapter on common garden helpers and how to study those numerous creatures on your own fields.

Reserving scenery, beauty or for recreation

The farmer may also reserve natural areas of beauty or of good recreational value. These will pay dividends, if not in potential agricultural tourism dollars, than in the wellbeing of the people who use the land.

The naturalist Enos Mills, a proponent of reservations of recreation and scenery, explained that the financial considerations of the matter weighed alone, the benefits to a landowner in improving the beauty of their property are considerable: it increases the value of the land, and provides an opportunity for selling recreation, relaxation and other services. While not every farmer wishes to run a bed and breakfast, a fishing lake or stream, artist's retreat, conference center, agricultural tourism location, etc., improving property values can increase the capital available to the farmer for expanding and continuing operations against adversity. There is little better use for marginal land, explains Mills, than conserving it for recreation and beauty.

Scenic places, if used for parks, will pay larger returns than by any other use that can be made of their territory. Parks, then, are not a luxury but a profitable investment...Although parks pay large dividends, they also have a higher, nobler use. They help make better men and women.

Outdoor life is educational. It develops the seeing eye, supplies information, gives material for reflection, and compels thinking, which is one of the greatest of accomplishments. Exercise in the pure air of parks means health, which is the greatest of personal resources, and this in turn makes for efficiency, kindness, hopefulness, and high ideals. Recreation in parks tends to prevent wasted life by preventing disease and wrong-doing. The conservation of scenery, the use of scenic places for public recreation parks, is conservation in the highest sense, for parks make the best economic use of the territory and they also pay large dividends in humanity....

...The courts have recently expressed definite and advanced views concerning scenic beauty. In Colorado, where water has a high economic value, a United States Circuit Court recently decided that the beneficial use of a stream was not necessarily an agricultural, industrial or commercial use, and that, as a part of the scenery, it was being beneficially used for the general welfare.

The question was whether the waters of a stream, which in the way of a lakelet and a waterfall were among the attractions of a summer resort, could be diverted to the detriment of the falls and used for power. The Judge said "No," because the waters as used, were contributing toward the promotion of the public health, rest, and recreation; and that as an object of beauty – "just to be looked at" – they were not running to waste but were in beneficial use.

He held that objects of beauty have an important place in our lives and that these objects should not be destroyed because they are without assessable value. The judge, Robert E. Lewis, said in part:

"It is a beneficial use to the weary that they, ailing and feeble, can have the wild beauties of Nature placed at their convenient disposal. Is a piece of canvas valuable only for a tentfly, but worthless as a painting? Is a block of stone beneficially used when put into the walls of a dam, and not beneficially used when carved into a piece of statuary? Is the test dollars, or has beauty of scenery, rest, recreation, health, and enjoyment something to do with it? Is there no beneficial use except that which is purely commercial?"...

...No nation has ever fallen from having too much scenery

And neither has any farm. Indeed, the economic, financial and ecological arguments for reserving areas for nature are overwhelming, though they will likely not bear upon those insane minds that would sell their inheritance too cheaply.

Lessons from Enos Mill's timberline observations (from the chapter on "The Forest Frontier" in "The Rocky Mountain Wonderland," 1915)

The timberline presents one of the most striking features of vegetation in an ecology: there exists a frontier across which no tree may grow. It is defined by a combination of temperature, moisture and other climatic factors that prohibit the growth of trees, but allows the growth of lesser plants. In his usual dramatic style, Enos Mills presents the dry chemistry of ecology into terms that illustrate the living struggle each plant and animal – that the living forest itself – undertakes to colonize beyond this limit. It is important to remember that life, in all its majestic forms, is consciously attempting to expand its territory and exhibits the same heroic determination seen in its first microorganic members on this planet.

How then does humanity hope to conquer its companions with chemicals and other senseless war? Why should humanity even try, when all life, as Mill's timberline does, presents a "united front" against the climate that would otherwise destroy all? Human children must eat, this is true, but they do not need to eat at the expense of wilderness. The thought is absurd. If natural reservations are held, wilderness will not only feed human children, but provide them shelter in their old age and grow their bodies and spirits to match their potential.

When Mills himself lives – for a short time – at the timber line, he gains first-hand experience, as an organism himself, what it is like for other organisms there. We must not forget our special ability as humans to observe other life forms, and use our similar life experiences to better understand our world. The tiny tree putting forth seeds not only demonstrates what happens to organisms under stress, but is a living, breathing lesson on courage to the humans who would pilgrimage to see it. And this is a lesson from ecology that is unquantifiable.

In the high mountains of the West wakes up the most indifferent visitor. The uppermost limit of tree-growth shows nature in strange, picturesque forms, and is so graphic and impressive that all classes of visitors pause to look in silent wonder. This is the forest frontier.

It appears as old as the hills and as fixed and unchanging as they; but, like every frontier, that of the forest is aggressive, is ever struggling to advance. To-day this bold and definite line is the forest's Far North, its farthest reach up the heights; but this simply marks where the forest is, and not where it was or where it is striving to be. Here is the line of battle between the woods and the weather. The elements are insistent with "thus far and no farther," but the trees do not heed, and the relentless elements batter and defy them in a never-ending battle along the timber-line.

From a commanding promontory the forest-edge appears like a great shore-line, as it sweeps away for miles along the steep and uneven sides of the mountains. For the most part it follows the contour line; here it goes far out round a peninsula-like headland, there it sweeps away to fold back into cove or canyon and forma forested bay. In Colorado and California this forest-line on the mountains is at an altitude of between eleven and twelve thousand feet. Downward from this line a heavy robe of dark forest drapes the mountains; above it the treeless heights rise cool and apparently barren, piled with old and eroded snowdrifts amid silent moorlands and rocky terraces.

The trees of timber-line are stunted by cold, crushed by snow, and distorted by prolonged and terrific winds. Many stretches appear like growths of coarse bushes and uncouth vines. They maintain a perpetual battle, and, though crippled, bent, dwarfed, and deformed, they are stocky and strong old warriors, determined, no weaklings, no cowards. They are crowded together and tangled, presenting a united front.

Few trees in this forest-front rise to a greater height than twelve feet. The average height is about eight feet, but the length of some of the prostrate ones is not far from the normal height. Wind and other hard conditions give a few trees the uncouth shapes of prehistoric animals. I measured a vine-like ichthyosaurus that was crawling to leeward, flat upon the earth. It was sixty-seven feet long, and close to the roots its body was thirty-eight inches in diameter. One cone-shaped spruce had a base diameter of four feet and came to a point a few inches less than four feet above the earth. Here and there a tough, tall tree manages to stand erect. The high wind either prevents growing or trims off all limbs that do not point to leeward. Some appear as though molded and pressed into shape. A profile of others, with long, streaming-bannered limbs, gives a hopeful view, for they present an unconquerable and conscious appearance, like tattered pennants or torn, triumphant battle-flags of the victorious forest.

The forest is incessantly aggressive and eternally vigilant to hold its territory and to advance. Winds are its most terrible and effective foe. To them is due its weird and picturesque front. Occasionally they rage for days without cessation, blowing constantly from the same quarter and at times with the rending and crushing velocity of more than one hundred miles an hour. These terrific winds frequently flay the trees with cutting blasts of sand. At times the wind rolls down the steeps with the crushing, flattening force of a tidal wave. Many places have the appearance of having been gone over by a terrible harrow or an enormous roller. In some localities all the trees, except the few protected by rocky ledges or closely braced by their encircling fellows, are crippled or overthrown.

Although I have visited timber-line in a number of States, most of my studies have been made on the eastern slope of the Continental Divide in Colorado. This ragged edge, with its ups and downs and curves, I have eagerly followed for hundreds of miles. Exploring this during every month of the year, I have had great days and nights along the timber-line. It was ever good to be with these trees in the clear air, up close to the wide and silent sky. Adventurers they appeared, strangely wrapped and enveloped in the shifting fog of low-drifting clouds. In the twilight they were always groups and forms of friendly figures, while by moonlight they were just a romantic camp of fraternal explorers.

Many a camp-fire I have had in the alpine outskirts of the forest. I remember especially one night, when I camped alone where pioneer trees, rusty cliffs, a wild lake-shore, and a subdued, far-off waterfall furnished sights and sounds as wild as though man had not yet appeared on earth. This night, for a time, a cave man directed my imagination, and it ran riot in primeval fields. After indulging these prehistoric visions, I made a great camp-fire with a monumental pile of tree-trunks and Limbs on the shore of the lake, close to the cliff. These slow-grown woods were full of pitch and the fire was of such blazing proportions that it would have caused consternation anywhere in Europe. The leaping, eager flames threw wavering lights across the lake on the steeply rising heights beyond. These brought the alarm cry of a coyote, with many an answer and echo, and the mocking laughter of a fox.

Even these wild voices in the primeval night were neither so strange nor so eloquent as the storm-made and resolute tree-forms that rose, peered, and vanished where my firelight fell and changed.

At most timber-lines the high winds always blow from one direction. On the eastern slope of the Colorado divide they are westerly, down the mountain. Many of the trees possess a long vertical fringe of limbs to leeward, being limbless and barkless to storm ward. Each might serve as an impressive symbolic statue of a windstorm. Permanently their limbs stream to leeward together, with fixed bends and distortions as though changed to metal in the height of a storm.

Whenever a tree dies and remains standing, the sand-blasts speedily erode and carve its unevenly resistant wood into a totem pole which bears many strange embossed pictographs. In time these trees are entirely worn away by the violence of wind-blown ice-pellets and the gnawings of the sand-toothed gales.

Novel effects are here and there seen in long hedges of wind-trimmed trees. These are aligned by the wind. They precisely parallel the wind-current and have grown to leeward from the shelter of a boulder or other windbreak. Apparently an adventurous tree makes a successful stand behind the boulder; then its seeds or those of other trees proceed to form a crowding line to the leeward in the shelter thus afforded. Some of these hedges are a few hundred feet in length; rarely are they more than a few feet high or wide. At the front the sandbla.sts trim this hedge to the height and width of the wind-break. Though there may be in some a slight, gradual increase in height from the front toward the rear, the wind trims off adventurous twigs on the side-lines and keeps the width almost uniform throughout.

During the wildest of winds I sometimes deliberately spent a day or a night in the most exposed places at timber-line, protected in an elkskin sleeping-bag. Wildly, grandly, the surging gusts boomed, ripped, roared, and exploded, as they struck or swept on. The experience was somewhat like lying in a diver's dress on a beach during a storm. At times I was struck almost breathless by an airy breaker, or tumbled and kicked indifferently about by the unbelievable violence of the wind. At other times I was dashed with sand and vigorously pelted with sticks and gravel.

This was always at some distance from tree, boulder, or ledge, for I took no risks of being tossed against trees or rocks. Many times, however, I have lain securely anchored and shielded beneath matted tree-growths, where in safety I heard the tempestuous booms and the wildest of rocket-like swishes of the impassioned and invisible ocean of air. The general sound effect was a prolonged roar, with an interplay of rippings and tumultuous cheerings. There were explosions and silences. There were hours of Niagara. In the midst of these distant roarings the fearful approach of an advancing gale could be heard before the unseen breaker rolled down on me from the heights.

The most marked result of cold and snow is the extreme shortness of the growing-season which they allow the trees. Many inclined trees are broken off by snow, while others are prostrated. Though the trees are flattened upon the earth with a heavy load for months, the snow cover affords the trees much protection, from both the wracking violence of the winds and their devitalizing dryness. I know of a few instances of the winter snows piling so deeply that the covered trees were not uncovered by the warmth of the following summer. The trees suspended in this enforced hibernating sleep lost a summer's fun and failed to envelop themselves in the telltale ring of annual growth.

Snow and wind combined produce acres of closely matted growth that nowhere rises more than three feet above the earth. This growth is kept well groomed by the gale-flung sand, which clips persistent twigs and keeps it closely trimmed into an enormous bristle brush. In places the surface of this will support a pedestrian, but commonly it is too weak for this; and, as John Muir says, in getting through, over, under, or across growths of this kind, one loses all of his temper and most of his clothing!

Timber-line is largely determined by climatic limitations, by temperature and moisture. In the Rocky Mountains the dry winds are more deadly, and therefore more determining, than the high winds. During droughty winters these dry winds absorb the vital juices of hundreds of timber-line trees, whose withered standing skeletons frequently testify to the widespread depredations of this dry blight. A permanent advance, too, is made from time to time. Here and there is a grove, a permanent settlement ahead of and above the main ranks. In advance of these are a few lone trees,

heroes scouting in the lead. In moist, sheltered places are seedlings and promising young trees growing up in front of the battle-scarred old guard. Advances on dry, wind-swept ridges are more difficult and much less frequent; on a few dry ridges these trees have met with a repulse and could be heard before the unseen breaker rolled down on me from the heights.

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With this environment it would be natural for these trees to evolve more hardiness than the present trees have. This would mean trees better fitted to contend with, and more likely to triumph over, the harsh conditions. Evolutionary development is the triumphing factor at the timber-line.

The highest timber-line in the world is probably on Mount Orizaba, Mexico. Frank M. Chapman says that there are short-leaved pines (*Pinus Montezumce*) from thirty to forty feet high, on the southern exposure of this peak at an altitude of about 13,800 feet. In Switzerland, along the steep and snowy Alps, it is sixty-four hundred; on Mt. Washington, about forty-five hundred feet. In the mountains of Colorado and California it is of approximately equal altitude, between eleven and twelve thousand feet. Advancing northward from California along the timber-line, one enters regions of heavy snowfall as well as of restricting latitude. Combined, these speedily lower the altitude of timber-line, until on Mt. Rainier it is below eight thousand feet. There is a noticeable dwarfing of the forest as one approaches the Land of the Midnight Sun, and in its more northerly reaches it comes down to sea-level to form the Land of Little Sticks. It frays out at its Farthest North just within the Arctic Circle. Most of the Arctic Ocean's icy waves break on treeless shores.

Everywhere at timber-line the temperature is low, and on Long's Peak the daily average is two degrees below the freezing-point. At timber-line snow may fall any day of the year, and wintry

conditions annually prevail from nine to ten months. The hardy trees which maintain this line have adjusted themselves to the extremely short growing-season, and now and then mature and scatter fertile seeds. The trees that do heroic service on all latitudinal and altitudinal timber-lines of the earth are members of the pine, spruce, fir, birch, willow, and aspen families. At timber-line on the Rocky Mountains there are three members each from the deciduous trees and the evergreens. These are the Engelmann spruce, limber pine, alpine fir, arctic willow, black birch, and quaking aspen.

A few timber-line trees live a thousand years, but half this time is a ripe old age for most timber-line veterans. The age of these trees cannot be judged by their size, nor by general appearance. There may be centuries of difference in the ages of two arm-in-arm trees of similar size. I examined two trees that were growing within a few yards of each other in the shelter of a crag. One was fourteen feet high and sixteen inches in diameter, and had three hundred and thirty-seven annual rings. The other was seven feet high and five inches in diameter, and had lived four hundred and ninety-two years!

One autumn a grizzly I was following — to learn his bill-of-fare — tore up a number of dwarfed trees at timber-line while digging out a woodchuck and some chipmunks. A number of the smaller trees I carried home for careful examination. One of these was a black birch with a trunk nine-tenths of an inch in diameter, a height of fifteen inches, and a limb-spread of twenty-two. It had thirty-four annual rings. Another was truly a veteran pine, though his trunk was but six-tenths of an inch in diameter, his height twenty-three inches, and his limbspread thirty-one. His age was sixty-seven years. A midget that I carried home in my vest pocket was two inches high, had a limb-spread of about four inches, and was twenty-eight years of age.

A limber pine I examined was full of annual rings and experiences. A number of its rings were less than one hundredth of an inch in thickness. At the height of four feet its trunk took on an acute angle and extended nine feet to leeward, then rose vertically for three feet. Its top and limbs merged into a tangled mass about one foot thick, which spread out eight feet horizontally. It was four hundred and nine years old. It grew rapidly during its first thirty-eight years; then followed eighteen years during which it almost ceased growing; after this it grew evenly though slowly.

One day by the sunny and sheltered side of a boulder I found a tiny seed-bearer at an altitude of eleven thousand eight hundred feet. How splendidly unconscious it was of its size and its utterly wild surroundings! This brave pine bore a dainty cone, yet a drinking-glass would have completely housed both the tree and its fruit.

Many kinds of life are found at timber-line. One April I put on snowshoes and went up to watch the trees emerge from their months-old covering of snow. While standing upon a matted, snow-covered thicket, I saw a swelling of the snow produced by something moving beneath. 'Plainly this is not a tree pulling itself free!' I thought, and stood still in astonishment. A moment later a bear burst up through the snow within a few yards of me and paused, blinking in the glare of light. No plan for immediate action occurred to me; so I froze. Presently the bear scented me and turned back for a look. After winking a few times as though half blinded, he galloped off easily across the compacted snow. The black bear and the grizzly occasionally hibernate beneath these low: matted tree-growths.

The mountain lion may prowl here during any month. Deer frequent the region in summer. Mountain sheep often take refuge beneath the clustered growths during the autumn storms. Of course the audacious pine squirrel comes to claim the very forest-edge and from a point of safety to scold all trespassers; and here, too, lives the cheery chipmunk.

This is the nursery, or summer residence, of many kinds of birds. The "camp-bird," the Rocky Mountain jay, is a resident. Here in spring the white-crowned sparrow sings and sings. During early

summer the solitaire, the most eloquent songster I have ever heard, comes up from his nest just down the slope to pay a tribute of divine melody to the listening, time-worn trees. In autumn the Clarke crow appears and, with wild and half-weird calls of merriment, devours the fat nuts in the cones of the limber pine. During this nutting, magpies are present with less business than at any other time and apparently without a plan for deviltry. Possibly they are attracted and entertained by the boisterousness of the crows.

Lovely wild-flower gardens occupy many of the openings in this torn and bristling edge of the forest. In places acres are crowded so closely with thrifty, brilliant bloom that one hesitates to walk through and trample the flowers. Here the columbine, the paintbrush, the monument-plant, and scores of other bright blossoms cheer the wild frontier.

Rarely are strangers in the mountains thoroughly aroused. They need time or explanation in order to comprehend or appreciate the larger scenes, though they do, of course, have periodic outbursts in adjectives. But at timberline the monumental scene at once has the attention, and no explanation is needed. Timber-line tells its own stirring story of frontier experience by a forest of powerful and eloquent tree statues and bold, battered, and far-extending figures in relief.

Only a few of the many young people whom I have guided to timber-line have failed to feel the significance of the scene, but upon one party fresh from college the eloquent pioneer spirit of the place made no impression, and they talked glibly and cynically of these faithful trees with such expressions as "A Dore garden!" "Illshapen fiends!" "How foolish to live here!" and "Criminal classes!" More appreciative was the little eight-year-old girl whose ascent of Long's Peak I have told of in "Wild Life on the Rockies." She paid the trees at timber-line as simple and as worthy a tribute as I have ever heard them receive: "What brave little trees to stay up here where they have to stand all the time with their feet in the snow!"

The powerful impressions received at timberline lead many visitors to return for a better acquaintance, and from each visit the visitor goes away more deeply impressed: for timberline is not only novel and strange, it is touched with pathos and poetry and has a life-story that is heroic. Its scenes are among the most primeval, interesting, and thought-compelling to be found upon the globe.

Lessons from Enos Mill's observations on woodpeckers and symbiotic relationships (from the chapter on "Dr. Woodpecker, Tree Surgeon" in "Spell of the Rockies," 1912)

Drs. Brett W. Benz, Mark B. Robbins, A. Townsend Peterson in their Evolutionary history of woodpeckers and allies (Molecular Phylogenetics and Evolution 40, 2006), after studying the relationships of three the Southeast Asian genera Dinopium, Reinwardtipicus, and Blythipicus, unexpected sister relationships were discovered that indicate "a complex geographic history for the Picidae, with multiple disjunct sister lineages distributed between the New World and Asia."

They suggest that the general and global migration of the species during the time of its origin confuses its origination point. And yet, while the geographical origination of the woodpecker is confused, the physical manifestation of its unique traits is less so. Although hesitant to conclude anything at this point, it is highly likely that "the phylogenetic position of Nesoctites suggests that the earliest woodpeckers were likely relatively small in size, lacked stiffened rectrices, and were strictly arboreal. If extant piculets are representative of the ancestral form, excavating holes and communication via drumming evolved basally to the Picinae+Picumninae."

The development of such a radically new niche through a novel feeding technique by the woodpecker allowed it to quickly colonize the globe. Such a trait is useful, both to the trees the birds rescue from insect damage and the forest at-large.

The special relationship that woodpeckers and trees share is little different from the special relationship that spiders and many plants share, or, for that matter, most carnivores and plants share. While some carnivores feed principally on other carnivores and it is difficult for a farmer to appreciate one species' protection over another's, Mills artfully uses the example of how woodpeckers defend trees to introduce and illustrate the idea of a species upon whom entire forests depend.

Likewise, we may draw upon the researches of Drs. Mark Robbins, A. Peterson, Arapad Nyari, Goujun Chenand Tristan Davis report in their Ornithological surveys of two reserves in Guangxi province, China, 2004–2005 (Forktail 22, 2006) that human intrusion into the area is greatly altering the kinds of birds that live there. "This subregion is heavily populated and almost all lowland forests have been cleared. Areas with relief are highly disturbed, with virtually all forest being secondary (MacKinnon 1997, personal observations). Recently, reserves have been established to protect remnants of this formerly continuous swathe of tropical and subtropical evergreen forest that once extended from the southern China coast south to northern Vietnam east of the Red River," they report.

While many species seemed to be stable and present, at both sites, hornbills, parrots and trogons were not recorded or were very scarce. Why? "Such families depend on relatively large tree-holes for nesting and roosting. In addition to large trees being scarce, both sites had a dearth of dead trees, apparently owing to removal for firewood. The scarcity of standing dead trees affected woodpeckers in particular. Excluding piculets which can thrive in relatively young forest, only a single woodpecker species was recorded at Shiwandashan (on two occasions) and two woodpecker species were recorded at Diding (once each). As many as eight woodpecker species might be expected to be resident (Winker et al. 1995)."

There is reason to hope: "We anticipate that with maturation of the forest, especially at Shiwandashan, the relative abundance of species will change dramatically, and species with good dispersal abilities may become established."

This lesson is one that we could learn from in the United States, where old trees and deadwood is feared for fire risks, but is no less vital for many of the same and similar species of birds. The reduction in biodiversity is highly undesirable, and the presence of members of various ages is all-important.

Although the eagle has the emblematic place of honor in the United States, the downy woodpecker is distinguished as the most useful bird citizen. Of the eight hundred and three kinds of birds in North America, his services are most helpful to man. He destroys destructive forest insects. Long ago Nature selected the woodpecker to be the chief caretaker — the physician and surgeon — of the tree world. This is a stupendous task. Forests are extensive and are formed of hundreds of species of trees. The American woodpeckers have the supervision of uncounted acres that are forested with more than six hundred kinds of trees.

With the exception of the California big tree, each tree species is preyed upon by scores, and many species by hundreds, of injurious and deadly insects. Five hundred kinds of insects are known to prey upon the oak, and a complete count may show a thousand kinds. Many of these insects multiply with amazing rapidity, and at all times countless numbers of these aggressive pests form warrior armies with which the woodpecker must constantly contend.

In this incessant struggle with insects the woodpecker has helpful assistance from many other bird families. Though the woodpecker gives general attention to hundreds of kinds of insects,

he specializes on those which injure the tree internally, — which require a surgical operation to obtain. He is a distinguished specialist; the instruments for tree-surgery are intrusted to his keeping, and with these he each year performs innumerable successful surgical operations upon our friends the trees.

Woodpeckers are as widely distributed as forests, — just how many to the square mile no one knows. Some localities are blessed with a goodly number, made up of representatives from three or four of our twenty-four woodpecker species. Forest, shade, and orchard trees receive their impartial attention. The annual saving from their service is enormous. Although this cannot be estimated, it can hardly be overstated.

A single borer may kill a tree; so, too, may a few beetles; while a small number of weevils will injure and stunt a tree so that it is left an easy victim for other insects. Borers, beetles, and weevils are among the worst enemies of trees. They multiply with astounding rapidity and annually kill millions of scattered trees. Annually, too, there are numerous outbreaks of beetles, whose depredations extend over hundreds and occasionally over thousands of acres. Caterpillars, moths, and saw-flies are exceedingly injurious tree-pests, but they damage the outer parts of the tree. Both they and their eggs are easily accessible to many kinds of birds, including the woodpeckers; but borers, beetles, and weevils live and deposit their eggs in the very vitals of the tree. In the tree's vitals, protected by a heavy barrier of wood or bark, they are secure from the beaks and claws of all birds except Dr. Woodpecker, the chief surgeon of the forest. About the only opportunity that other birds have to feed upon borers and beetles is during the brief time they occupy in emerging from the tree that they have killed, in their flight to some live tree, and during their brief exposure while boring into it.

Beetles live and move in swarms, and, according to their numbers, concentrate their attack upon a single tree or upon many trees. Most beetles are one of a dozen species of Dendroctonus, which means "tree-killer." Left in undisturbed possession of a tree, many mother beetles may have half a million descendants in a single season. Fortunately for the forest, Dr. Woodpecker, during his ceaseless round of inspection and service, generally discovers infested trees. If one woodpecker is not equal to the situation, many are concentrated at this insect-breeding place; and here they remain until the last dweller in darkness is reached and devoured. Thus most beetle outbreaks are prevented. Now and then all the conditions are favorable for the beetles, or the woodpecker may be persecuted and lose some of his family; so that, despite his utmost efforts, he fails to make the rounds of his forest, and the result is an outbreak of insects, with wide depredations. So important are these birds that the shooting of a single one may allow insects to multiply and waste acres of forest.

During the periods in which the insects are held in check the woodpecker ranges through the forest, inspecting tree after tree. Many times, during their tireless rounds of search and inspection, I have followed them for hours. On one occasion in the mountains of Colorado I followed a Batchelder woodpecker through a spruce forest all day long. Both of us had a busy day. He inspected eight hundred and twenty-seven trees, most of which were spruce or lodge-pole pine. Although he moved quickly, he was intensely concentrated, was systematic, and apparently did the inspection carefully. The forest was a healthy one and harbored only straggling insects. Now and then he picked up an isolated insect from a limb or took an egg cluster from a break in the bark on a trunk. Only two pecking operations were required. On another occasion I watched a hairy woodpecker spend more than three days upon one tree trunk; this he pecked full of holes and from its vitals he dragged more than a gross of devouring grubs. In this case not only was the beetle colony destroyed but the tree survived.

Woodpecker holes commonly are shallow, except in dead trees. Most of the burrowing or boring insects which infest living trees work in the outermost sapwood, just beneath the bark, or in the inner bark. Hence the doctor does not need to cut deeply. In most cases his peckings in the wood are so shallow that no scar or record is found. Hence a tree might be operated on by him a dozen times in a season, and still not show a scar when split or sawed into pieces. Most of his peckings simply penetrate the bark, and on living trees this epidermis scales off ; thus in a short time all traces of his feast-getting are obliterated. I have, however, in dissecting and studying fallen trees, found a number of deep holes in their trunks which woodpeckers had made years before the trees came to their death. In one instance, as I have related in "The Story of a Thousand-Year Pine" in "Wild Life on the Rockies," a deep oblong hole was pecked in a pine nearly eight hundred years before it died. The hole filled with pitch and was overgrown with bark and wood.

Woodpeckers commonly nest in a dead limb or trunk, a number of feet from the ground. Here, in the heart of things, they excavate a moderately roomy nest. It is common for many woodpeckers to peck out a deep hole in a dead tree for individual shelter during the winter. Generally neither nest nor winter lodging is used longer than a season. The abandoned holes are welcomed as shelters and nesting-places by many birds that prefer wooden-walled houses but cannot themselves construct them. Chickadees and bluebirds often nest in them. Screech owls frequently philosophize within these retreats. On bitter cold nights these holes shelter and save birds of many species. One autumn day, while watching beneath a pine, I saw fifteen brown nuthatches issue from a woodpecker's hole in a dead limb. Just what they were doing inside I cannot imagine; the extraordinary number that had gathered therein made the incident so unusual that for a long time I hesitated to tell it. However, early one autumn, Mr. Frank M. Chapman climbed up the mountainside to see me, and, while resting on the way up, he beheld twenty-seven nuthatches emerge from a hole in a pine.

By tapping against dead tree-trunks I have often roused Mother Woodpecker from her nest. Thrusting out her head from a hole far above, she peered down with one eye and comically tilted her head to discover the cause of the disturbance. With long nose and head tilted to one side, she had both a storky and a philosophical appearance. The woodpecker, more than any other bird of my acquaintance, at times actually appears to need only a pair of spectacles upon his nose in order fully to complete his attitude and expression of wisdom. J The downy woodpecker, the smallest member of a family of twenty-four distinguished species, is the honored one. He is a confiding little fellow and I have often accompanied him on his daily rounds. He does not confine his attacks to the concealed enemies of the trees, but preys freely upon caterpillars and other enemies which feast upon their leaves and bloom. He appears most content close to the haunts of man and spends much of his time caring for orchards and cleaning up the shade trees. One morning in Missouri a downy alighted against the base of an apple tree within a few feet of where I was standing. He arrived with an undulating flight and swept in sideways toward the trunk, as though thrown. Spat! he struck. For a moment he stuck motionless, then he began to sidle round and up the trunk. Every now and then he tapped with his bill or else stopped to peer into a bark-cavity. He devoured an insect egg cluster, a spider, and a beetle of some kind before ascending to the first limb.

Just below the point of a limb's attachment he edged about, giving the tree-trunk a rattling patter of taps with his bill. He was sounding for something. Presently a spot appeared to satisfy him. Adjusting himself, he rained blows with his pick-axe bill upon this, tilting his head and directing the strokes with an apparently automatic action, now and then giving a side swipe with his bill, probably to tear out a splinter or throw off a chip. In six minutes his prey was evidently in sight. Then he enlarged the hole and slightly deepened it vertically. Pausing, he thrust his head into the

hole and his bill into a cavity beyond. With a backward tug he pulled his head out, then his bill, and at last his extended tongue with a grub impaled on its barbed point. This grub was dragged from the bottom of a crooked gallery at a point more than three inches beyond the bottom of the pecked hole. A useful bread-getting tool, this tongue of his, — a flexible, extensible spear.

In another tree he uncovered a feast of ants and their eggs. Once a grasshopper alighted against another tree-trunk up which he was climbing. Downy seized him instantly. In one tree-top he consumed an entire tent-caterpillar colony. In four hours he examined the trunks, larger limbs, and many of the smaller ones of one hundred and thirty-eight apple trees. In this time he made twenty-two excavations, five of which were large ones. Among the insects devoured were beetles, ants, their eggs and their aphids, a grasshopper, a moth or two, and a colony of caterpillars. I followed him closely, and frequently was within a few feet of him. Often I saw his eyes, or rather one eye at a time; and a number of times I imagined him about to look round and with merry laugh fly away, for he frequently acted like a happy child who is closely watching you while all the time merrily pretending not to see you. Yet, in all those four hours, he did not do a single thing which showed that he knew of my nearness or even of my existence!

Examining each tree in turn, he moved down a long row and at the end flew without the slightest pause to the first tree in the next row. From here he examined a line of trees diagonally across the orchard to the farther corner. Here he followed along the outside row until he flew away. The line of his inspection, from the time I first saw him until he flew away, formed a big letter "N."

During a wind-storm in a pine forest a dead tree fell near me and a flying limb knocked a downy, stunned, to the earth, by my feet. On reviving in my hands, he showed but little excitement, and when my hands opened he pushed himself off as though to dive to the earth; but he skimmed and swung upward, landing against a tree-trunk about twenty feet distant. Up this he at once began to skate and sidle, exploring away as though nothing had happened and I were only a stump.

Lessons from Enos Mill's observations on meadows and the balance between trees and grasses and the resulting diversity of habitat for animals implying a balance of trees and lesser plants on the farm (from the chapter on "Mountain Parks" in "Rocky Mountain Wonderland," 1915)

The forest functions as a single organism, and the presence of meadows is as important to the health of the forest as any stand of trees. The open spaces are used by animals in social functions, and the rich life the grasses sustain provide excellent food for the animals using the nearby trees for shelter. The grasses check the spread of disease and pests between trees, the spread of fire, and facilitate stability in the ecosystem of the forest. The delicate balance between the trees and grasses is important and those who would farm trees in orchards for fruit, nuts, timber, vegetables, or other products, would be wise to learn from it: the combined close proximity of trees in beds and the wide spacing between beds – with the planting of smaller bush and annual crops – imitates with success the natural balance of nature. As much as grasses and trees hate each other, they need each other.

It provides a lesson, too, on the migration of plants: the grasses and trees are always moving their stands about and the sedentary life of plants on a farm (with plants only occupying beds or even specific locations within a bed) is highly abnormal. Yet, the abnormal behavior of cattle who remain (largely) sedentary while wandering around a pasture not 1% of their natural range occurs with the same dynamic the farmer provides their plants and animals all the resources they need, and there is no reason for them to move about.

Thus, the strawberry and raspberry can send out runners every year into the bed and remain in youthful production while their neighbors the trees are content to remain in rows; in a well-tended field, there is finally peace between the meadow and the forest.

The farmer must always learn from nature, and try to bring peace to the world: by the farmer's stewardship, the lion may lay down with the lamb, the wolf with the calf, the grasshopper among the beans, and the forest among the meadows.

The grassy park openings within the mountain forests are among the great charms of the outdoor world. These are as varied in their forms as clouds, delightfully irregular of outline. Their ragged-edged border of forest, with its grassy bays and peninsulas of trees, is a delight. Numbers are bordered by a lake or a crag, and many are crossed by brooks and decorated with scattered trees and tree-clumps. Others extend across swelling moraines. All are formed on Nature's free and flowing lines, have the charms of the irregular, and are model parks which many landscape gardeners have tried in vain to imitate. They vary in size from a mere grass-plot to a wide prairie within the forest.

'Park' is the name given to most of these openings, be they large or small. There are many of these scattered through the Rocky Mountains. North, South, and Middle Parks of Colorado are among the largest. These larger ones are simply meadows on a magnificent scale. Each is an extensive prairie of irregular outline surrounded by high forest-draped mountains with snowy peaks, — an inter-mountain plain broken by grassy hills and forested ridges. Here a mountain peninsula thrusts out into the lowland, and there a grassy bay extends a few miles back into the forested mountains...

...The majority of parks or meadow gardens which decorate the forests of the Rocky Mountains probably owe their existence to fire. Trees and grass are endlessly contending for the possession of the earth. In this incessant silent struggle a sweeping fire is generally of advantage to the grass. Trees suffer more from fire than does grass. It is probable that repeated fires enable the grass to hold the plains and prairies against the encroachments of the trees. Each forest fire commonly gives the grass possession of a part of the area formerly dominated by the forest. Usually both grass and trees are prompt to seize any fire-cleared area. The grass may be first to come, or some space may be wet or in some other way unfavorable to tree seed but encouraging to grass seed.

While forest fires bring many of these parks, others are glacier meadows, lake-basins which time has filled with sediment and sodded with grass. Many are due to the presence of water, either outspreading surface water or an excess of underground water just beneath the surface, — to streams visible or invisible. A few result from boggy places which result from impaired drainage caused by landslips or fallen trees. Thousands were made by beaver dams, — are old beaver ponds that filled with sediment and then grassed over.

Most parks that owe their origin to forest fires have charcoal beneath the surface. A little digging commonly reveals charred logs or roots. Occasionally, too, a blackened tree-snag stands suggestively in these treeless gardens. In the competition for this territory, in which grass, spruces, aspens, and kinnikinick compete, grass was successful. Just what conditions may have been favorable to grass cannot be told, though probably one point was the abundance of moisture. Possibly the fire destroyed all near-by seed trees, or trees not destroyed may not have borne seed until the year following the fire. Anyway, grass often seizes and covers fire cleared areas so thickly and so continuously with sod that tree seeds find no opening, and grass thus holds possession for decades, and, in favorable places, possibly for a century.

Trees grow up around these areas and in due time the grassy park is surrounded by a forest. The trees along the edge of this park extend long limbs out into it. These limbs shade and kill the

grass beneath. Tree seeds sprout where the grass is killed, and these seedlings in turn produce trees with long limbs reaching into the park. These shade and smother more grass and thus advance the forest another limb's length. Slowly but surely the park is diminished.

Struggling trees may sometimes obtain a place in advance of the others or a start in the centre of the park, and thus hasten the death of the park and speed the triumph of the trees. A mere incident may shorten the life of a park. A grizzly bear that I followed one day, paused on a dry point in a park to dig out some mice. In reaching these he discovered a chipmunk burrow. By the time he had secured all these he had torn up several square yards of sod. In this fresh earth the surrounding trees sowed triumphant seeds, from which a cluster of spruces expanded and went out to meet the surrounding advancing forest. Fighting deer sometimes cut the sod and thus allow a few tree seeds to assert themselves. Wind may blow down a tall tree which lands in the edge of the park. Along its full length grows a line of invading forest. Occasionally the earth piled out by a gopher, or by a coyote in digging out a gopher, offers an opportunity that is seized by a tree seed. An ant-hill in a meadow may afford a footing for invading tree seeds. On one occasion a cliff tumbled and a huge rock-fragment bounded far into the sloping meadow. Trees sprang up in each place where the rock tore the sod and also around where it came to rest in the grass.

These breaks in the sod made by animals or other agencies do not always give triumph to the trees. Seedlings may eagerly start in these openings, but, being isolated, they are in greater danger, perhaps, than seedlings in the forest. Rabbits may nibble them, woodchucks devour, or insects overrun them. The surrounding grass may smother them and reclaim the temporarily lost opening.

But, though only one tree may grow, this in due time shades the grass, a circle of young trees rise around it, and these in turn carry forward the work of winning territory. At last the park is overgrown with trees!

Glacier meadows may be seen in all stages of evolution. The lake-basin gouged by a glacier goes through many changes before it is covered by a forest and forgotten. No sooner does ice vanish and a glacier lake appear than its filling-in is commenced. Landslips and snowslides thrust boulders and cliff-fragments into it; running water is constantly depositing sand and sediment upon its bottom. Sedge and moss commence covering its surface as soon as its water becomes shallow. In due time it becomes a bog with a thick covering like a wet mattress, composed of the matted roots of sedge and grass. Over this, wind and water deposit earthy matter, but centuries may pass before the bog is filled in sufficiently to have a dry surface and produce grass and flowers and finally trees.

Once while strolling through a forested flat in central Colorado, I concluded from the topography of the country that it must formerly have been a glacier lake. I procured tools and sank a shaft into the earth between the spruces. At a depth of two feet was a gravelly soil-deposit, and beneath this a matting of willow roots and sedge roots and stalks. These rested in a kind of turf at water-level, beneath which were boulders, while under these was bed-rock. Numerous romantic changes time had made here.

Many of these meadows are as level as the surface of a lake. Commonly the surface is comparatively smooth, even though one edge may be higher than the other. I measured one meadow that was three thousand feet long by two hundred and fifty feet wide. Tree-ranks of the surrounding forest crowded to its very edge. On the north the country extended away only a foot or two higher than meadow-level. On the south a mountain rose steeply, and this surface of the meadow was four feet higher than the one opposite. The up-the-mountain end was about three feet higher than the end which had been the old outlet of the lake. The steep south shore had sent down more material than the level one on the north. In fact, water-level on the north shore, though concealed by grass, was almost precisely the same as when the waters of the lake shone from shore to shore. In one

corner of the meadow was an aspen grove. From the mountain-side above, a landslide had come down. Rains had eroded this area to bed-rock and had torn out a gully that was several feet wide on the slope below. This washed material was spread out in a delta-like deposit on the surface of the meadow. Aspens took possession of this delta.

Glacier meadows are usually longer-lived than other mountain parks. In favorable places they sometimes endure for centuries. Commonly they are slowly replaced by the extending forest. The peaty, turfy growth which covers them is of fine matted roots, almost free of earthy or mineral matter, and often is a saturated mattress several feet in thickness. The water-level is usually at the surface, but during an extremely dry time it may sink several inches or even a few feet. If fires run during a dry period of this kind, the fire will burn to waterlevel. The ashes of this fire, together with the mineral matter which it concentrates commonly form a soil-bed which promptly produces trees. Sometimes, however, grass returns. Thus, while fire brings forth many meadows in the forest, it sometimes is the end of one evolved from glacial action. A landslip often plunges a peninsula of soil out upon a glacial meadow. This is usually captured by trees in a year or two.

These parks make ideal camping-places, — wild, beautiful, and alluring in every season. I have enjoyed them when they were white with snow, mysterious with cloud and mist, romantic with moonlight, and knee-deep in the floral wealth of June. Often I have burst out upon a sunny meadow hidden away in the solitude of the forest. As it lies silent in the sunshine, butterflies with beautifully colored wings circle lightly above its brilliant masses of flowers. Here bears prowl, deer feed, and birds assemble in such numbers that the park appears to be their social centre. In these wild gardens the matchless solitaire is found. Often he sings from the top of a spruce and accompanies his song by darting off or upward on happy wings, returning and darting again, singing all the time as if enchanted.

Among the hundreds of these happy resting grounds in which I have camped, one in the San Juan Mountains has left me the most memories. I came there one evening during a severe gale. The wind roared and thundered as impressively as breakers on a rock-bound shore. By midnight the storm ceased, and the tall trees stood as quietly as if content to rest after their vigorous exercise in the friendly wrestling match with the wind. The spruces had become towering folded flags of fluffy black. After the gale the sky was luminous with crowding stars. I lingered in the centre of the opening to watch them. The heavens appeared to be made of many star-filled skies, one behind the other. The farthest one was very remote, while the closest seemed strangely near me, just above the tops of the trees.

Many times I have come out of the subdued light of the pathless forest to enjoy these sunny openings. Often I have stood within them watching the butterflies circling in the sun or a deer and her fawns feeding quietly across, and, as I looked, I have listened to the scolding of the squirrel and the mellow ringing of the woodpecker far away in the forest. Here I have watched the coming storm, have enjoyed its presence, and in its breaking have seen the brilliant bow rest its foundations in front of the trees just across the meadow. Sometimes the moon showed its soft bow in the edge of the advancing or the breaking storm.

One evening, before the moon looked into this fairy garden, I watched a dance of crowding fireflies. They were as thick as snowflakes, but all vanished when the moonlight turned the park into fairyland. Rare shadow etchings the tall, short-armed spruces made, as they lay in light along the eastern border of this moonfilled park. A blue tower of shadow stretched from a lone spruce in the open to the forest wall beyond. As the moon rose higher, one of the dead trees in the edge of the forest appeared to rise out of the darkness and stand to watch or to serve. Then another rose, and presently two appeared side by side and edged into the light. They might have been conversing. As

the night advanced, the shadow of the spruces shortened as their shadow points moved round to the north. As the moon sank behind a mountain, the dead trees settled back into the darkness, and, just before light left the park, the two broken trees moved behind a shadow and vanished. They were scarcely out of sight when the weird cries of a fox sounded from the farther edge of the woods...

The ability of a single person to do much good is remarkable: let us not forget here that Enos Mills campaigned alone for the creation of the Rocky Mountain National Park, and other parks in the Rocky Mountains, singlehandedly leading to the reservation of critical natural resources for all posterity. It is always possible to do what needs done when it needs done; with courage, any right thing is possible.

CHAPTER THREE:
OF THE FOOD OF PLANTS

Feeding plants is the chief art of husbandry

The chief art of husbandry is to feed plants to the best advantage. But how shall that be done, unless it is known what is the food of plants?

All non-toxic chemicals are essential to life – whether plant, animal, or microorganism – in some quantity, and can become toxic in surplus quantity.

All the following materials contribute (in some manner) to the growth of plants, but it is disputed which among them actually increases the plant: 1) Niter, 2) Water, 3) Air, 4) Fire, 5) Soil.

I do not mention or consider as a "food" that acid spirit of the air so much talked of, since by its eating of iron bars it appears too much of the nature of aqua-fortis[71] to be a welcome guest alone to the tender vessels of the roots of plants.

[71] "Aqua-fortis" means "strong water," and may be understood in this case to be "corrosive." He is, of course, referring to the element known today as "Oxygen." Oxygen is essential to plant life. At night, when plants cannot undertake the photosynthesis of sugar, they breathe in Oxygen and exhale Carbon dioxide (just like animals). However, in balance, their photosynthesis is more efficient and they emit more oxygen during the day than they breathe at night.

It is well that Tull did not assume that there is only one true food of plants as many of his contemporaries did. Just as there is no one true food of human beings, plants rely on numerous chemicals from their environment to live. Yet it is forgivable that his contemporaries, with less insight than Tull had, would believe there to be a single food of plants because the atomistic nature of soil was not widely understood in the earliest parts of the 18th Century. "Soil," was believed to be a homogeneous matter, as was "air," though both soil and air are composed of many numerous chemicals and life forms.

Tull understood that there are many foods of plants, but seeks to understand which is most important: which one can the farmer best increase?

Modern science knows better: the soil is composed not only of numerous kinds of chemicals, but many living organisms as well. Some of these are also present in the air. It is safe enough to say that all non-toxic chemicals are necessary to any life form in some quantities, whether plant, animal, fungi or microorganism. And, for that matter, any chemical that is generally non-toxic can become toxic in surplus quantity. Modern botany follows Tull's lead and classifies the most important chemicals to plants in terms of macronutrients and micronutrients, defining them by which are most important for the farmer to apply to the soil. Macronutrients, which are believed to be most important for the farmer to provide, include two divisions: primary (the very most important for the farmer to provide) and secondary. The primary Macronutrients are Nitrogen, Potassium and Phosphorus. The secondary Macronutrients are Calcium, Magnesium and Sulfur. The micronutrients are Boron, Copper, Iron, Chlorine (in Chloride form), Manganese, Molybdenum and Zinc.

1) Niter helps plants eat their food like a knife helps people eat their food, but is as harmful if directly applied to the roots as a knife would be if applied to the stomach

Niter[72] is useful to divide and prepare the food of plants, and may be said to nourish plants in much the same manner as my knife nourishes me by cutting and dividing my meat.[73] But when niter is applied to the root of a plant, it will kill the plant as certainly as a knife that is misapplied will kill a man. This proves that niter is, in respect of nourishment, just as much the food of plants as arsenic is the food of rats. The same can be said of all salts.

2) Water carries dissolved chemicals in it, is necessary for cellular regulation and the photosynthesis of sugar

Water, from Van-Helmont's experiment, was by some scientists thought to be the food of plants. But these scientists were deceived by not observing that water always has in it dissolved soil. It is a vehicle for soil. This is confirmed by Dr. Woodward. Nobody has, that I know of, maintained the argument that water is the food of plants since Dr. Woodward's arguments.[74],[75]

It is fortunate that through Tullian tillage, both macronutrients and micronutrients are easily increased in the soil. –A.B. & M.C.

[72] Niter is today defined as the mineral form of potassium nitrate, KNO_3, also known as saltpeter. However, historically the term has been similar to that of natrium, a Latin word for sodium and has been very vaguely defined. As such, it has been applied to a variety of other minerals and chemical compounds, including Sodium nitrate, Sodium carbonate and Potassium carbonate. Tull uses it in the sense of the numerous kinds of agricultural salts used in fertility, especially those from manures. –A.B. & M.C.

[73] The topic of plant nutrition can (and does) fill volumes, and will not be discussed at length here. However, Tull is asserting that the salt's principle purpose in the soil is not as a food itself, but as the means by which food is more easily obtained by the plant. This has some grounding in chemistry: adding a salt to the soil increases the osmotic pressure of the soil against the plant when the soil and plant are in solution. Tull is also correct in his understanding that salts can bind with other nutrients in solution to make them in a more ingestible form. Tull is also correct in observing that the salts decrease the compactness of a soil. –A.B. & M.C.

[74] Water is essential for cellular regulation, photosynthesis and is a nutrient in its own right, and while Tull understands fully that there is matter in the water that is needed for the life of a plant, and that water is essential to all life, he differentiates between the water and (what we would call "atoms") suspended in the water. –A.B. & M.C.

[75] The use of water by aqueous plants, while discussed in greater depth in later chapters, confirms the theory that the greater part of water's nutrition lies in the dissolved materials in it. In modern agriculture, aquaponics – the growth of terrestrial plants in water – is undertaken by dissolving within the water sufficient nutrients for the plant's health. But yet, even then, the plants must be anchored in gravel and allowed periodically to dry their roots so they may breathe and exhale gases through their roots. –A.B. & M.C.

3) Air is a vehicle for nutrition like water, air is composed of chemicals necessary for the life of a plant and the photosynthesis of sugar. Air is not the principle food of plants, otherwise there would be little difference between "good" lands and "poor" lands: all lands share the same air

Air is as necessary to the life of vegetables as the vehicle of water is; it is a vehicle as water is.[76]

Some modern "virtuosi" have affirmed, from the same (and worse) arguments as the water proponents, that air is food of plants. Mr. Bradley is a chief (if not the only) proponent of this fantasy, and has put forth several arguments.[77] It is fit that his arguments should be answered, and is more fittingly done when I show he has answered all of his own arguments!

His first argument is that of Helmont, and is thus related in Mr. Bradley's general treatise *Of Husbandry and Gardening, Vol. I:* "Who dry'd Two Hundred Pounds of Earth, and Planted a Willow of Five Pounds weight in it, which he water'd with Rain, or distill'd Water; and to secure it from other Earth getting in, he cover'd it with a perforated Tin Cover. Five Years after, weighing the Tree, with all the Leaves it had born in that Time, he found it to weigh One Hundred Sixty-Nine Pounds Three Ounces; but the Earth was only diminished about Two Ounces in its weight," (page 36). On this experiment of Helmont Mr. Bradley grounds his Airy Hypothesis.

But let the Airy Hypothesis be examined fairly, and see what may be thence observed!

Helmont's tin cover was to prevent any other soil from getting in. This tin cover must also prevent soil from getting out (except what entered the roots). A willow is a very thirsty tree, and must have drunk in five years time several tons of water. This water would have carried with it a great quantity of soil in solution (probably many more times than the tree's weight[78]). That the amount of soil was not increased during the experiment proves only that as much soil was poured in with the water as did enter the tree.[79]

[76] In modern agriculture, aeroponics – the growth of terrestrial plants in air – is undertaken by vaporizing within water sufficient nutrients for the plant's health and spraying that vapor onto plant roots suspended in air. The air is sometimes charged with Carbon Dioxide or Oxygen or other gasses. The anchorage of the plants is undertaken by ropes, hooks and other rigging. Aeroponics has limited profitable application, and when done must periodically allow the plant roots to dry so they may breathe and exhale gasses through the roots for maximum effect. –A.B. & M.C.

[77] Air, as previously discussed, is composed of a mixture of chemicals and life that is essential for the plant's life – especially the photosynthesis of sugar. Tull grasps this fully, as shall be shown, but differentiates between the air itself and the matter in it, unable to understand that the air itself is composed of matter! –A.B. & M.C.

[78] The body of an animal receives a much less increase in weight than its perspirations amount to, as Sanctorious's experiments with the Static Chair demonstrate that 5/8 of the nourishment (or weight equal to it) taken by a man passes off by unobservable perspiration.

[79] Patient scientists like Tull can see that air provides the necessary carbon for sugar production in plants. Tull, in this chapter, imagines the air to carry nutrients in the form of dust. The idea that there could be invisible nutrients that compose the air — or that plants could change the state of these invisible nutrients from gas to solid — was beyond his capacity to imagine even if it might be an easy thing for modern scientists to conceive. Invisible particles like atoms could be thought dust-like to their predecessors. The editor would use this as lesson for the modern reader: the capacity of science to advance is limited by the ability of scientists to imagine things as they truly are...and scientific imagination is limited only by a familiarity with the nature it seeks to study.

The weight of the tree, even when green, must consist of soil AND water. Air could be no part of it because air is of no greater specific gravity than the incumbent atmosphere.[80] There is no weight in air[81], and therefore it was not part of the one hundred sixty-nine pounds, three ounces.

Whether the soil did enter to nourish the tree or whether the soil entered the tree to simply pass through it to the air may be examined by what the tree did consist of after putrefaction[82]. That the matter remaining after the putrefaction of the tree was soil is a proof that the soil remained in the tree to nourish and augment it. Certainly the tree could not leave what it did not first take, nor be augmented by what passed through it? According to Aristotle's doctrine—and Mr. Bradley's too (in the same volume, page 72, "Putrefaction resolves it again into Earth, its first Principle.").

Nature has directed animals and vegetables to seek what is most necessary to them. At the time an animal fetus has a necessity of respiration, it is brought into the open air by birth so the lungs can fill with air. As soon as a calf, lamb, etc. is able to stand, it applies to the teat for food without any teaching.

In a like manner, Mr. Bradley remarks in his same volume I, "That almost every Stem and every Root are formed in a bending manner under Ground, and yet all these Stem become straight and upright when they come above Ground, and meet the Air; and most roots run as directly downwards and shun the Air as much as possible," (page 10). Could anything more plainly show the intent of nature than Mr. Bradley's remark does? Air is most necessary to the tree above the ground (to purify the sap by the leaves, as the blood of animals is purified by lungs)[83] and roots seek the earth for food in solution, shunning the air that would dry them up and destroy them?[84]

Our power of observation is poor, so we are granted the ability to reason with logic. Science is a practice of reason, and so it is impossible for even the greatest observer to achieve a complete understanding of a phenomenon. Science depends on familiarity with natural phenomenon and imaginative capacity as much as observation just as a barrister who familiarizes themselves with the spirit of laws is able to argue upon even obscure cases with little research. Tull was a barrister, and perceived the natural law as something tangible and real, a word of the universal and immutable will of God. –A.B. & M.C.

[80] No doubt Jethro Tull would have been surprised to learn that the air and water consists of matter that the willow could have used for its "augmentation." The process of sugar production relies on the particles (atomic and molecular) suspended in air and water as much as the air and water themselves. –A.B. & M.C.

[81] Air does have weight and mass, if you count the atoms and other "dust" that Tull leaves out of his calculation. Though it changes with humidity, pressure, temperature and other factors, at sea level and 70 degrees Fahrenheit, air weighs 7.492 pounds per cubic foot (x 10^-2). —A.B. & M.C.

[82] Read "putrefaction," understand "dehydration." —A.B. & M.C.

[83] It is the modern understanding that roots require air as well as water, and are responsible for respiration just as leaves are. –A.B. & M.C.

[84] Tull's logic is flawed: the roots of a plant seek the soil, but the leaves of the plant seek air and sunlight! And yet, simultaneously, Tull is vindicated: sea plants, of which he (strangely!) makes no mention, access no air at all, but react with chemicals dissolved in the water. The truth lies, from modern understanding, in the need of plants for water, carbon dioxide and sunlight in the leaf. Water and carbon dioxide can be received from the roots as well as the leaves, but the sunlight must be received by the leaves. Sunlight, more than air, is a food of plants; soil and sunlight together are the foods of plants. –A.B. & M.C.

No one truth can possibly contradict or interfere with any other truth, but one error may contradict and interfere with another error.

Mr. Bradley and other authors, I think, are of the opinion that plants of different natures are fed by a different sort of nourishment. From this they understand that a crop of wheat takes up all that is particular to that grain, and that a crop of barley takes all that is proper to it, and that a crop of peas takes all that is proper to it, and so on. They think that when no more of these plants will grow on a land, all the particles are drawn off that are proper to those crops. Then, by fallow, dung and the influences of the heavens, the soil is again replenished with new nourishment to supply the same sorts of crops all over again.

This, if true (as they affirm it to be), would prove that air is not the food of vegetables! The air is itself more homogeneous than the soil, it is so homogeneous as it is that it could never afford such different matter as they imagine. Neither is it probable that the air should afford the wheat nourishment for only one year, ending at the end of that year. Or that the same year it should nourish barley in one field and wheat in another, and peas in a third. Their hypothesis of air as food interferes with and contradicts their doctrine dictating the necessity of crop rotation.

To give the benefit of the doubt, I can suppose that by "air," they mean "suspended particles of soil," or "the effluvia that float in the air." But the quantity of these suspended particles is too small to augment vegetables to the bulk that the plants arrive at.[85] And, if air could nourish some plants by the effluvia that are carried by it, this would be argument against those who argue that air is the food of plants!

The proponents of the Air Hypothesis might as well believe that martins and swallows are nourished by the air because they live on flies and gnats that they catch in the air.

If, as they say, the soil is of little use to plants except to keep them fixed and steady, there would be no difference in the value of rich or poor land, fertilized or unfertilized land. Both serve to keep plants fixed and steady equally well! If water or air was the food of plants, I cannot see the necessity of fertilizer or tillage.

4) Fire, or heat, is necessary to the life of plants, but is certainly not a food of any living creature, and is in fact a herbicide

No plant can live without heat, though some degrees more or less of it is necessary to different sorts of plants. Some are almost able to keep company with the salamanders that live in the hottest exposures of the hot countries! Others live like fishes under water, or in cold climates where the sun

[85] I think the suspended particles of water to be more likely because water carries a greater quantity of soil than air does in proportion to the difference in their specific weights: water is eight hundred times heavier than air, and is therefore likely to have eight hundred times more suspended particles than air. We see that the amount of particles suspended in water to be sufficient for the maintenance of aquatic plants. But air is never able to maintain or nourish any plant by its scanty charge of suspended particles. And as for the aloes, sedums and other plants that are supposed to grow suspended I the air, this is a fallacy: these plants seem to grow but do not, unless it is meant that they constantly grow lighter. They live on the juices that they received when they grew in the earth, and when suspended in the air, they diminish in weight until they grow to nothing. [Tull references a study wherein aloes, sedums and other plants were removed from the soil, suspended in air and observed to see if they would die from lack of nourishment –A.B. & M.C.]

has littler influence. But that fire is the food of plants, I don't know any author except Mr. Laurence who says, "They are True Fire-Eaters." And I guess that even he does not seem to intend that this expression should be taken literally.

And yet, if Mr. Laurence had meant it in the plain sense that his words import, perhaps he might have been much nearer the truth than Mr. Bradley is with his air hypothesis. Fire is nothing else but the minutes parts of terrestrial matter put into a violent motion[86] then those minute parts of that motion are the same matter as when not in violent motion. Those minute particles the true nourishment of plants, and fire differs from soil only in the motion.

It is said that fire is a fluid-like thing that pervades all bodies, it is said that in all bodies fire lies latent until it is excited by violence to become hot. At rest, it is said, fire is cold because it is against the essential property of fire.

The idea that fire could ever be cold would never enter the skull of a peasant; we will define fire to be the action of burning, not the matter which burns, and see that fire is as different from the food of plants as air is.[87] Every heat may be said to be a different degree of fire, yet we may distinguish the degrees by their different effects: heat warms, but fire burns; heat helps to grow plants, fire destroys plants.

5) Soil, the True Food of Plants: niter (and other salts) prepare the soil, water and air move it, heat helps to ferment and speed the conveyance of it

That which nourishes and augments a plant is the true food of it. Every plant is made of earth, and the growth and true increase of a plant is the addition of more earth. Niter (and other salts) prepare the soil, water and air move it, and heat helps to ferment and speed the conveyance of the juices in the soil.

If water, air and heat is taken away from a plant, it dies; if soil is taken away from it a plant it does not grow

Suppose the water, air and heat of a plant could be taken away, the plant would remain a plant (though a dead one). But suppose that the soil of a plant is taken away, what would become of the plant? Mr. Bradley would certainly be looking long at it before he found it in the air amongst his "specifick" or "qualities."

[86] Since Tull's time, science has learned that fire is a state of matter known as "plasma." It is an energetic state that has properties of solid, liquid and gas, and occurs when ionic atoms or molecules are excited. Tull's understanding is not too far from the truth. –A.B. & M.C.

[87] Indeed, the true food of plants may also be the fuel of fire. Fire is so greedy of that food that it carries away all the food that comes within reach of the flames. I do not know how, but the soil can be divested of its vegetative particles by fire. [Humus burns because it is mostly organic matter –A.B. & M.C.]

Too much niter (or other salts) corrodes a plant, too much water drowns a plant, too much air dries the roots, too much heat (or fire) burns a plant, but too much soil is impossible, unless the soil is misapplied and the plant is wholly buried by it (starving it of air).

Too much niter (or other salts) corrodes a plant, too much water drowns a plant, too much air dries the roots of a plant, too much heat (or fire!) burns a plant, but too much soil a plant can never have (unless the plant is wholly buried, and in that case the soil is as equally misapplied as air or niter would be to the roots).

No, too much soil or too fine of soil can never possibly be given to the roots. They never receive so much of it as to forfeit the plant—unless the plant is deprived of leaves to purify the soil.

Any soil will feed any plant, so long as air, water and heat are not lacking

Soil is so surely the food of all plants that with the proper share of the other elements that each species of plant requires, I find that any common soil will nourish any kind of plant.[88]

The only variation of soil (except of richness) seems to be the different heat and moisture it has. If heat and moisture are adjusted, any soil will nourish any sort of plant. Let thyme and rushes change places and both will die. But remove the dry-hill soil wherein the thyme grows and put it into the watery bottom wherein the rushes grow, and carry the moist soil wherein the rushes grow up to the hill, and the rushes will grow in the soil that grew the thyme and the thyme will grow in the soil that the rushes grew in. More or less water makes the same soil fit for the growth of thyme or rushes.

So it is also for heat: my soil, when it has in the oven the same degree of heat that each sort of plant requires, can maintain plants even from the Indies. Plants differ as much from one another in the degrees of heat and moisture requirements as fish differ from salamanders.

Jethro Tull's Suppliment

Transmutation of elements impossible: discussion of experiments by Boyle and Newton

There is no need to have recourse to transmutation, for whether air or water, or both, are transformed into earth or not, the thing is the same if it is earth when the roots take it. None the less, we are convinced that neither air nor water alone, as such, will maintain plants.

I can find no clear proof of the reality of transmutation: the only one that I know of is that Sir Isaac Newton offers for water being transmuted into earth, which he quotes from Mr. Boyle; but that

[88] There is no need to have recourse to ideas of transmutation in refutation of the fact that soil is the true food of plants. Whether air or water or both are transformed into soil or not, it is the same thing: if it is soil when the roots take it, we are convinced that neither air nor water alone (as such) will maintain plants! Such metamorphoses may be properly enough considered in dissertations purely concerning matter, as is the discovery of what the component particles of earth are. But these things are not necessary to be known in relation to the maintaining of vegetables.

experiment was made by a friend of Mr. Boyle, and Mr. Boyle himself was so far from believing it a real transmutation that he gave a reasons to prove the impossibility of it.

The substance of the experiment here follows: an ounce of rain water was distilled nearly two hundred times, and there remained six drachms of white powder and a considerable quantity of water left behind. This powder Mr. Boyle suspects might be partly obtained from the glass vessel wherein it was distilled rather than from the ounce of water, neither the glass nor the remaining water having been weighed. Whether the glass was in fact diminished (which could not be known but by weighing), or if the remaining water was above two drachms, it would have been a demonstration that all the powder did not proceed from the ounce of water. I suppose that some part of the water (being volatile, and passing pores that scarce any other fluid does) might get off through the hot glass, or otherwise in such a number of distillations; and that then there must be (for supply of that loss) some adventitious matter in the six drachms of powder, though the water that remained should weigh but just two drachms [a drachm is 1/8 fluid ounce].

This powder must consist of parts of the glass, and of such matter as the distillations had separated from the pores of the water.

Mr. Boyle thinks, that "if the water be truly an homogeneal body, it is difficult, if not impossible, to conceive that it can be transmuted: for how can the bare convention of the parts of a fluid into a concrete, after the specific gravity?" Which is as much as to say, that water being specifically lighter, cannot become powder, which is specifically heavier: and water after distillation (being more pure, though never perfectly pure) always becomes specifically lighter than before; and the matter that is left in the still, heavier; water changing its specific gravity in proportion to the degree of its purity."

Water considered abstractly from the charge of other matter (chiefly earth, which is suspended in it) is at this time, I think, generally agreed to be homogeneal, consisting of extremely small, smooth, hard, porous, spherical particles of equal diameters, incompressible, void of taste, and having no quality that renders a body heterogeneous.

But indeed (as far as I am informed), Mr. Boyle and his friend, at the time this experiment was made, did not at all distinguish any difference between the particles (or corpuscles) of water and the other matter suspended in it (mistaking the vehicle for the thing carried) and therefore they, as they seem to consider both confusedly, could have no distinct idea of transmutation. And yet it has deceived some who, one would think, should have examined more narrowly into the matter than to mistake a separation of earth from water for a change of water into earth.

But this will cease to be a wonder, when we see what that miracle of a man Sir Isaac Newton brings for argument to countenance a hypothesis of his: "Water is by heat converted into vapour, which is a kind of air, and by cold into ice, which is a stone; and this stone is convertible into water again by heat, as vapour is by cold."

But I believe the learned will now subscribe to the opinion, that water, when carried in the air, under the form (or rather name) of vapor, is not air of any kind; and that when it is under the form of ice it is not really stone; it never having all the properties of air, or of stone.

His other instances are of like validity; for an egg being turned into an animal is no more a real transmutation than the royal oak transmuting into the Prince when the Prince was taken out of it; or that a man's house, when he is gone abroad, is transmuted into a man.

A maggot is a little fly enveloped in a thin skin, which, as a garment, hides the wings and legs; and continues to be the same fly when uncovered, as a man is the same man when his garments are off, as when on; the fly grows bigger, and so does a boy when he becomes a man, but still continues to be the same person, without any real transmutation, unless he should become infallible.

Sir Isaac says, that "all birds, beasts, fishes, insects, trees, and plants; grow and increase out of water, and aqueous and saline tinctures: and on putrefaction of all them revert into water or an aqueous liquor again."

Also in treating of comets, he says, "They seem necessarily requisite, from whose condensed exhalations and vapours all that moisture, which is consumed in vegetation and putrefaction, and turned into dry earth, may by degrees be continually resupplied and recruited; for all vegetables do entirely grow and increase from liquors: and then, as to their greatest part, do turn, by putrefaction into dry earth, and a slime perpetually is precipitated to the bottom of putrefying liquors."

"From hence the quantity, or bulk of dry earth, must continually increase, and the liquors, or moisture of our globe continually decrease, and, at last, be quite evaporated and lost, if they had not as continual a supply from some part or other of the universe."

Now I must beg leave to confess, that I can see no force in these arguments, either for the transmutation of water, or any such necessity of comets.

And even though transmutation should be supposed (which by no means can be granted), yet no such consequence of the decrease of water on our globe can be drawn from Sir Isaac's argument, but the contrary.

For he says, that birds, beasts, fishes, insects, trees, and plants, on putrefaction, all of them revert into water, or an aqueous liquor again.

How then does it follow, that the water of our globe is never consumed or diminished, or that it can want any supply of moisture?

The water brought to the land in vapor from the sea, we see returns by the rivers to the sea again; all of it, either before it in part enters other bodies, or after it returns out of them, except such of it that is carried back in vapor.

The smoothness, hardness, and other properties of the corpuscles of water seem to render them incapable of the cohesion which is necessary for incorporating with earth or other bodies, yet where these corpuscles are so very few in number as to lose their fluidity, some of them may rest in other bodies for a time, but afterwards either slide out, or are expelled by heat; or else more of the same corpuscles come to them, and restore them to fluidity: for it is not likely they should remain always confined by other bodies since their slipperiness, sphericity, and equal smallness of their diameters enables them to pass the pores of gold, and where one corpuscle passes, all may pass; some sooner, some later, as there are innumerable degrees of dryness and moisture.

A violin is said to require fourscore years after the making ere it obtains that degree of dryness that gives it perfection of sound: and after all, cannot be supposed perfectly dry, while it has pores permeable to the water vapor that floats in the ambient air: and some such pores will it have until time (that devourer of things) has destroyed its texture, and reduced it to the very same earth that water carried in at the vegetable roots; which earth will then again become as dry as when water seized it, and took it up for the trees out of which the violin was made. Green wood would grow drier but not lighter, if water were transmuted in it.

I can see no reason to think that any part of the pure element (or corpuscles) of water is consumed by vegetation, but rather, that the same water which served for the production of one plant, may afterwards as well serve for other plants successively and for all other its uses as long as the world shall last: nor do I think there is any diminution of that element on our globe since it was

first created; for as much water going out of some bodies as goes into others, keeps the quantity the same, and the balance even betwixt it and earth, without a necessity of any supply from comets.[89]

From Sir Isaac's transmutation-arguments we may learn, that a man never ought to depend entirely upon his own for support of his own hypothesis.

Sir Isaac's death seems scarce a stronger proof of his being human than the whole contexture of these arguments is. To favor transmutation, he says, the bodies of animals and plants, on putrefaction, revert into water or an "aqueous liquor" again: but in favour of the necessity of comets, on account of the consumption of water, he says, that those bodies turn by putrefaction into dry earth!

It is difficult for the ignorant to understand the terms of the learned, but, by this "aqueous liquor," I understand a mixture of earth and water, and suppose a saline tincture is only a term of the learned of the same signification; but that a liquor and dry earth should be the same thing, is what, I own, I can by no means comprehend.

It is certain that by the consumption of water, Sir Isaac does not mean the annihilation of it, but that it was transmuted into dry earth. If this were so, an animal or vegetable would weigh as much when putrefaction had reduced it to dry earth as it would when living. Yet, we find, that this remaining dry earth is only a very small part of the weight of living animal or plant. What then becomes of the remainder of the whole weight whereof the living bodies consisted?

Why, I suppose it goes the same way that the aqueous part of the nourishment of a living body goes, after a short stay therein: it either perspires into the atmosphere, or sinks into the ground, all except what remains for increase of the bodies, which is but a very inconsiderable part of the water, and none at all when the bodies are at their full growth, or declining.

I cannot conceive how the liquors of moisture of our globe, should ever be all or in any part lost by being evaporated, unless it should fly off to some other part of the universe, instead of being continually supplied from thence. Were it not for evaporation, the watery climate would be useless to vegetables and animals, except to such as live with salt-water in the sea; for neither springs, nor rivers, nor other fresh water would be found on our globe: or if so great a quantity of liquor or moisture should be transmuted into dry earth, and resupplied from any other part of the universe, the bulk and diameter of the earth must continually increase; and what consequences such an increase might have is above my inquiry; but I suppose the attraction to the sun would continually increase in proportion to the access of matter continually coming to our globe.

But what alterations such increased bulk and weight might cause in the motion or orbit of this our planet astronomers can only judge; and I am not informed that any of them have ever observed any increase of the earth's diameter.

As far as this hypothesis of Sir Isaac's relates to agriculture I think we need not fear it so as to abstain from raising as many vegetables as we can. There seems to be no danger of our vegetables consuming the water they imbibe, for in general we have rather too much water than too little and it is observed, that three or four wet summers make a scarcity, and many dry ones make a plenty in our islands. And if it were not the same in other countries, wet summers would not cause the price of corn here to be treble what it is reduced to by dry summers.

[89] The truth of what Tull speaks has broad implications, and the circulation of water is key to understanding the Gaian theory discussed at the end of this edition. The necessity for keeping water pure from poisons such as fertilizers, pesticides and herbicides is self-evident by the nature of water cycling, and the importance of this natural cycle is paramount to the maintenance of life. – A.B. & M.C.

We have therefore more to fear than hope for the tails of comets, because the matter of them mixing with our atmosphere would likely to bring both famine and pestilence amongst the inhabitants of our earth; the former by the aqueous part, and the later by the noxious exhalations of which, as well as of watery vapors, the tails of comets are supposed to consist.

It is allowed that the fine particles of earth brought to the ground by water enriches the soil, but yet much water in the growing season is very pernicious to corn, though not to weeds, they being naturally adapted to the soil (some of them aquatics, some amphibious, and others that cannot bear so much water, grow on such lands whereon the water did not long remain, but sinks down or runs off very soon).

I may add, that if the intense heat of actual fire in almost 200 distillations is not able to break the corpuscles of water or destroy their texture so as to change that element into earth, or any other matter, there can be no possibility of such a transmutation from that very small degree of heat which water suffers by the weak ferment it encounters in the vessels of plants and animals. [90]

[90] Plants are able to break the bonds of water (which is composed of two Hydrogen atoms and one Oxygen atom) through chemical means. The water is incorporated with air to form sugar, which is a hydro – carbon (composed of water, Hydrogen and Oxygen, and Carbon). Water is used in many ways in both plants and animals, but very importantly in maintaining cellular pressure: water is retained as water to allow for the transfer of chemical messages and nutrition within and between cells. –A.B. & M.C.

CHAPTER FOUR:
THE PASTURE OF PLANTS

Plants graze upon the soil from within the soil, difficulties of direct observation

Cattle feed on vegetables that grow upon the soil's external surface, but the vegetables themselves first receive the nourishment they give to animals from beneath the soil's surface. The pasture of cattle has been known and understood in all ages of the world because it has been able to be directly inspected, but the pasture of plants, being beyond the observation of the senses, is only discovered through the use of reason.[91]

The inability for direct observation seems to be one principle cause that agriculture, the most necessary of all arts, has been treated of by authors more superficially than any other art whatever.

It is this pasture I will now endeavor to describe.

The pasture of plants is not the food of plants: the pasture is the location of the food; soil being solid, liquid and gas, roots are able to graze upon inner surfaces of the soil

The food of plants has been proved to be soil, but the pasture is not the soil itself: the pastures are the inner surfaces of the soil from which the soil[92] is taken by the roots.[93] There are two sorts of inner surfaces: natural and artificial. They are similar except in their creation.

[91] It may be because reason is required to learn the pasture of plants that the pasture of plants has (for all I could find) remained until now undiscovered by the writers of agriculture: when writers of agriculture, in discussing the soil and vegetation, come near to learning the pasture of plants, they are lost in the shadow of it and wander in a wilderness of obscure expressions (such as "magnetism," "virtue," "power," "specific quality," "certain quality," and the like). And when a man (no less sagacious than Mr. Evelyn!) has sought the pasture of plants through every one of the "Mazes of Occult Qualities," even looking to the "metaphysicks" for an answer, he declares that he cannot determine whether the thing he seeks is corporal or spiritual. For him and other like writers there is no light of Reason to ease their wanderings in search of the real substance of the pasture of plants; Mr. Evelyn, and other like writers (and their readers, too!) are left more in the dark to find it than the roots that feed upon it.

[92] Soil is solid, liquid and gas simultaneously, and thus roots are able to graze upon small surfaces within the soil. –A.B. & M.C.

[93] This pasture of plants has never been mentioned or described by any author that I know of, and I am quite at a loss to find any other term to describe it by. I call it the "inner" or "internal" surface to distinguish it from the outer and external surfaces—that is, the surface on which we tread. Admittedly, "inner surfaces" may be thought an absurd expression, but it is the adjective we use for expressing something from within (the substantive seeming to express only what is without it). It is a term that is used to describe the inside of a thing that is hollow, as the pores and inner surfaces of the soil are. The surfaces that are the pasture of plants are not mathematical surfaces, for those are only imaginary. I use the sense of expression in such a way because the vegetable pasture is not within the soil, but within the surfaces of the divided parts of the soil.

Mouths (lacteals) on the roots consume soil suspended in water from the surfaces of the pores and cavities the roots are in

The mouths (or lacteals) of the roots take soil suspended in water from the surfaces of the pores and cavities that the roots are in. A plant cannot separate particles from the inner surface of the soil without the assistance of water, which helps loosen them for the roots.

It is also possible that the niter of the air may be necessary to relax these internal surfaces so as to render the particles of those internal surfaces capable of being separated.[94]

Since the grosser vegetable particles, when they have passed through a plant by and with the water (their vehicle) fly up into the air invisibly, it is not likely that the same particles should, in the soil, fall off unaided from the inner surfaces of pores. And, if they should fall off, they might fly away as easily before they entered the plants and a soil would become poorer through time. Indeed, we see the contrary: that soil is always richer by being frequently turned and exposed to the atmosphere.

Soil fertility partially measured by the quality of these pastures, as it allows plants to graze upon the food in the soil (the usual measure of fertility being a quantification of this food); soil naturally becomes more fertile over time in fallow

Soil is not divested or robbed of this food by any other means—except by fire. Indeed, when no vegetables are allowed to grow in a soil, the soil will grow richer.[95]

Plow or harrow the soil as often as you please, expose it to the sun, let horses walk paths into it, let it be covered by water at the bottom of ponds or ditches, grind the soil to powder and expose or treat it to any other method possible (except burning by fire) and, instead of losing, the soil will gain more fertility.[96] These inner surfaces, by their number and size, determine the specific gravity of each soil. The larger the inner surfaces, the lighter the soil.

[94] Tull's hypothesis is not too far from the truth: the salt of nitrogen and other compounds indeed makes it easier for plants to eat by increasing the pressure of the soil in solution against the roots and by combining with native chemicals to make them in a more ingestible state. –A.B. & M.C.

[95] Tull was not the only one to observe this. Masanobu Fukuoka also realized that fertility increased in fallow. Both Tull and Fukuoka then sought the means by which to increase fertility without fallowing the field. This leads to an understanding of how humus is made. –A.B. & M.C.

[96] It is important to recognize that Tull does not say that the pores of the soil are the food of plants, but that the pores of the soil are the pastures upon which plants "graze" their food. The soil may be fertile, but the plants cannot access the fertile soil without contact with the "internal" surface of the soil. Increasing the porosity of the soil does not itself increase the fertility of the soil, but it does increase the amount of food available in that soil to plants by easing their burrowing and grazing, much as opening a pasture gate does not increase the fertility of the field cattle graze upon...even if it does increase the amount of food available for the cows to produce fruit (milk). –A.B. & M.C.

Water gives more fertility to the soil than it takes from it; rain water and spring water are equally nutritious to the soil

It is true that rain water is as nourishing to plants as spring water, though the spring waters have more soil suspended in them. Yet we must consider that rain water may have been many times exhaled into the air and may still have vegetable particles retained within it, even if the amount of vegetable particles would not be so great a quantity as would be found in the spring water. No matter its source, water usually gives much more food to the soil than it takes from it.[97]

Water carries plant food with it into the soil

Water carries in its internal surfaces particles of soil fine enough to enter roots[98]. I have seen in my experiments that a great quantity of particles will pass out of roots that had been set in rain water.

Yet, I also see aquatic plants have their roots in the soil. It seems that much of the soil contained in even the clearest water is too large to enter roots.[99] Very few plants will live long with the thin pasture that water affords them: I have not found one plant yet that has lived more than a year in water without some soil added to it.

The difference between natural and artificial pastures

Natural pasture alone will suffice to furnish a country of few inhabitants with vegetables enough food. But if the artificial pasture of agriculture were taken out of this world, it is to be feared that all those of populous countries (especially those towards the confines of the frigid zones) would be obliged to become anthropophagi[100] (as people do in uncultivated regions often do).

The artificial pasture of plants, on all parts of the globe where used, maintains many more people than the natural pasture. And in the colder climates, I believe it will not be extravagant to say, ten times as many. If the process of agriculture is improved (as I hope to show it is not difficult to do) the same land could maintain twice as many people more.

The natural pasture is not only less than the artificial in quantity of soil, but also has fewer pores and cavities (which make it more pervious to roots of all vegetables) and requires of the plants more force to break through partitions of pores and cavities by the roots (so that the roots of weak plants are excluded from as many cavities and pores, and cannot gain benefit from their

[97] Desert lands are less fertile than wetlands. –A.B. & M.C.

[98] Rain carries with it dissolved atmospheric and oceanic chemicals, spring water also carries with it dissolved minerals, both from the rain it originated as and from the rock it seeped through. –A.B. & M.C.

[99] The problem is not so much the size of the food, but the quantity: many aquatic plants do absorb nutrients through the water and simply use their roots as anchorage, but many fresh waters have too little nutrition to support a large plant and they must supplement their diet with soil from the ground. –A.B. & M.C.

[100] Anthropophagi: cannibal (man-eater). –A.B. & M.C.

pasturage).[101] In artificial pasture, roots may extend to their utmost, without any barricades to their way.

To expand pastures of cattle requires additions of land, expansion of plant pastures requires tillage; amount of pasture in a cubic foot of soil may exceed 6.98 square miles per cubic foot of soil

While the pastures of cattle may not be enlarged without moving fences, the pastures of plants may be increased without an addition of land: it is by the division of the soil itself that the surface area of the soil and the pasturage is increased!

A cubic foot of soil has six surfaces, totaling an area of 6 square feet.

Divide this foot into inches. There are 1,728 cubic inches to a foot, and each has 6 inches in surface area, a total surface area of 72 square feet.

Divide these inches into quarters (slicing them in half each way), and there will be 6,912 cubic half-inches, each with a surface area of 3 square inches, a total surface area of 144 square feet.

Divide the cubic half inches into quarters to make 27,648 cubic quarter inches. Each will have a surface area of 1.5 inches and they will have a total area of 288 square feet.

Divide it again, into 110,592 cubic 1/8 inches, and the surface area will increase to 576 square feet. Divide it again into 442,368 cubic 1/16 inches and the surface area will increase to 1,152 square feet. Divide it again into 1,769,472 cubic 1/32 inches and the surface area becomes 2,304 square feet.

2,304 square feet in the same cubic foot of soil that, if had it remained undivided to the size of a grain of sand, would have only had 6 square feet of area. Divide it to cubic 1/512 inches (the size of silt particles is 1/500 cubic inches) and there are more than 36,864 square feet (6.98 square miles) of pasture in that cubic foot.

And the soil is divisible nearly infinitely, exposing to the plant roots new pastures to graze upon!

Though poor land does not afford pastures so well stocked with food as rich land does, we may compensate by dividing poor land more so that what the poor land lacks in quality it makes up for in quantity.

[101] Many beneficial macroorganisms that live within, on top and above the field (including worms, bacteria, birds, ants and other insects, mice, snakes, etc.) depend on loose soil as well.

So-called "No-Till" and "Reduced-Till" systems have been recently developed in an attempt to reduce evaporation, claiming that tillage increases evaporation and can reduce soil moisture by 25% or more. Sometimes, they advocate against tillage to reduce the nitrogen in the soil in situations where farmer have polluted their ground with nitrogen fertilizers. But whether the soil is too dry or wet, nitrified or denitrified, Tull's method should be used: not only does Tullian tillage increase both water and water capacity of soils, it does much to repair the damage of nitrogen and other pollution.

Tull's method can be further improved by the use of weeds in natural reservations: like the tillage and hoeing itself, the weeds will increase microbial activity and provide food for the microbes (Iowa State University, *Conservation Tillage Systems and Management Crop Residue Management with No-Till, Ridge Till, Mulch Till, First edition, MWPS-45*; 1992). –A.B. & M.C.

Tillage is better than manure, but tillage and manure are better than tillage alone

The common methods of dividing soil are these: by manure, by tillage or by both (for *vis unita fortior*)[102].

Jethro Tull's Supplement

Plants eat both whole soil and parts of soil

As to the fineness of the pabulum of plants, it is not unlikely that roots may become no grosser particles than those on which the colors of their bodies depend. But to discover the size of those corpuscles of plant food, Sir Isaac Newton thinks, will require a microscope that with sufficient distinctness can represent objects five or six hundred times bigger than they appear to the naked eye[103].

My microscope indeed is but a very ordinary one, and when I view with the liquor newly imbibed by a fibrous root of a mint, it seems more limpid than the clearest common water, nothing at all appearing in it.

Either roots must insume the soil as they find it in whole pieces or else particles of the soil are separated by roots.[104]

Artificial pasture does not injure or reduce natural pasture, as they each provide the same kind of food to the plants; observations on grazing various kinds of plants on natural pastures and artificial ones

That sanfoin, clover and grass, when their roots reach pulverized soil, increase their production above one hundred times beyond other members of their species without access to the artificial pasture shows just how greatly the artificial pasture of plants exceeds the natural pasture.

There were two aisles in the middle of a poor field of worn out sanfoin that were pulverized the preceding summer in the manner described in the chapter of sanfoin. Here not only the sanfoin adjoining to these intervals recovered in strength, blossomed, and seeded well, but also the grasses that grew among it were as strong and had as flourishing a color as had a dung-heap been laid in the intervals. Also many other weeds came out from the edges of the unplowed ground (which must have laid dormant a great many years) and grew higher and larger than ever were seen before in that field. But above all, there was a weed among the sanfoin adjoining to these intervals that generally accompanies it (bearing a white flower, some call it white weed, others, ladies' bedstraw): some of

[102] "Vis unita fortior" means "each, together, is stronger." Tillage is less without manure, manure is less without tillage. Tull *does not ever* say, as he is sometimes accused, "tillage is manure" or "tillage is a replacement for manure." —A.B. & M.C.

[103] Some atoms are very small: water molecules are about 0.278 nanometers in diameter. Magnifying them 100,000,000 times would bring them to be an inch in diameter. —A.B. & M.C.

[104] Both are true, in some cases, and usually both occur on a plant at the same time. Sometimes the food is brought in whole and "digested," either in specialized organs or in cells, and other times only particular elements are allowed to pass through chemical gates. –A.B. & M.C.

the white weed plants that stood near the aisles were, in the opinion of all that saw them, increased to a thousand times the bulk of those of the same species that stood in the field three feet distant from such pulverized earth.

The land had lain still several years after its artificial pasture was lost, and all the plants in it had only the natural pasture to subsist on and became extremely small and weak.

And when by pulverization the artificial pasture came to be added to this natural pasture, it became rich enough without any manure to produce this extraordinary effect upon the plants whose roots reached into it.

And what I have said of any one species of plants in this respect may be generally applied to the rest.

None of the natural vegetable pasture is lost or injured by the artificial, but, on the contrary, it is mended by being mixed with it, and by having a greater communication between pore and pore.

Supplement of the Fifth Edition

Fertilizers can lead to malnourishment; Tullian tillage provides balanced nutrition to plants

Though the subject has been fully developed in previous chapters, it bears being repeated here that fertilizers and amendments (whether organic or inorganic) are costly and time consuming to apply, and harmful to the soil and life forms (plants and animals alike) of both your garden and the entire world. Avoid fertilizer use altogether.

Yet there is another danger to fertilizers: they result in malnourishment. Most fertilizers are used in order to promote a plant's growth, making it grow bigger than it would have on its own. In growing more rapidly than was natural, the plants are weakened in other ways. While these plants may produce bigger fruits, they are also at higher risk for disease or damage from insects, microorganisms, weather, and other factors. These plants are usually malnourished or with a nutrient deficiency due to the imbalanced nutrition they receive. Malnourished plants are less able to defend themselves against disease or predators. The higher yield that the fertilizers bring carries with it an increased risk of losing that yield from disease or damage. It also increases the costs necessary to secure that harvest, such as by making pesticide application more necessary.

Yet it remains true that Tullian fertilization (through tillage) provides all the nutrients a plant requires and there is no plant malnutrition because it helps the soil produce all those macronutrients and micronutrients the plants require in the proportions the plants require through the creation of humus.

That fertilizers potentially damage the soil by causing acidification, water poisoning, salinization, and other problems requires no further discussion, having already been examined in depth previously.

CHAPTER FIVE:
OF DUNG (MANURE)

Dung is what ferments within the soil, and includes green manures; green manures are superior to animal manures because they better help soil microorganisms

Under the name of dung we may also understand whatever ferments[105] within the soil, such as green vegetables covered in the ground, etc. All sorts of dung and compost contain some matter which, when mixed with the soil, ferments therein.

This fermentation helps divide the soil in a similar but inferior way to tillage, and adds very little matter – beneficial or detrimental – to the soil

This fermentation dissolves, crumbles and divides the soil. Fermentation is the chief (and almost only) use of dung, because the quantity of purely earthy matter in it is so very small that, after a perfect putrefaction, the dung or compost appears to bear a most inconsiderable proportion to the soil it is designed to manure.[106]

Manure is salty and poisonous to plants

The fermenting ability of manure chiefly is owed to the salts wherewith it abounds. Yet, a very little of this salt applied alone to a few roots of almost any plant will (as in my mint experiments with common salt) kill it. This proves that it is the purpose of salt not to nourish plants, but to dissolve and divide the soil so it may afford nutriment to the mouths of the plant roots.

Manure is a determent to the flavor of plants grown with it or in it, and encourages diseases in the field

It is, I suppose, upon the account of the acrimonious nature of these salts that florists have banished dung from their flower gardens. And there is, I am sure, much better reason to prohibit the use of dung in the kitchen garden on account of the ill taste it gives to roots and plants—especially if the dung is made in the towns.

[105] Fermentation is an excellent description for the process by which manure is worked upon by microorganisms. And, as with the fermentation of foods, a high sugar content is demanded if the soil is not to be poisoned by protein-loving (and toxin-forming) microorganisms. An acidic, sugary manure is required for the best results. Such a manure is gained from plant matter, if manure is to be used at all. While animal manures on a field can be beneficial, they are not as beneficial as plant manures, and pose additional risks of disease to the animals (and humans) who would use the crop later; animal manures should be treated with the caution that toxic wastes warrant and preferably should be composted before they are applied to crops. –A.B. & M.C.

[106] Fresh manure is about 75% water, dried manure is typically 10% water. Sometimes manure is watered down further to aid in its distribution on the field–A.B. & M.C.

It is a wonder how "delicate" palates will not tolerate eating their own or their beast's feces, but will accept it if it becomes only a little more putrefied, evaporated, combined with all sorts of filth and nastiness and then received by roots that grow amongst it. Indeed, I do not admire those "learned" palates that are accustomed to the *Goût of silphium*, or *garlic la chair venee* or *mortified venison*,[107] each of which equals the stench and rankness of the sort of city-muck that they relish and approve growing their plants within. And yet it is the people whose squeamish stomachs become nauseated at and abhor to receive these foods of "nobles" that are called "vulgar!" The food of nobles is so little different from the filth with which they fertilize their gardens that the water wherein a nobleman's cabbage is boiled stinks—even as the water wherein a cabbage from a poor undunged field is boiled has no manner of unpleasant savor.

While Dung is observed to give great encouragement to the production of worms, the carrots in a dunged garden are much worm-eaten. And they say that a carrot, bred in a dunghill, has none of that sweet relish that a field carrot has. Dung spoils the fine flavor of our food. The dunged vineyards of Languedoc produce nauseous wine and a proverb in that country: "poor people's wine is best because they carry no dung to their vineyards."

Plant, or green, manures are best, but they are less effective than animal manures unless they are buried in the soil or allowed to mulch – more discussed in the Chapter on Compost

Vegetable dung, unless the vegetable is buried alive in the soil, makes much less ferment in it and consequently divides the soil less than animal dung does. But the dung of vegetables is much more wholesome for the use of edible roots and plants than that of animals is.[108]

Animal wastes are toxic

The wastes of animal bodies released by perspiration can be so noxious as to kill the animal that emits them—if the animal is confined to receive them back by breathing in the air that is replete with them. An animal shut up in an airtight room will soon die, and yet these seem to be the most harmless of all sorts of animal excrements of the air. How noxious then could manure be?

[107] Silphium ("Giant Fennel") was a plant related to asafetida, harvested for its strong flavor in culinary use, and its reputation as a powerful medicinal herb. It once grew in Libya, and was used as a means by which to abort a pregnancy. Silphium was overharvested in the wild before it could be brought under consistent cultivation and is extinct: attempts at domestication failed, perhaps due to poor Roman farming methods that destroyed the delicate African soil it grew in. To Jethro Tull, its name conferred the identical meaning as asafetida, which literally translates to "Devil's Dung," and – to many tastes, "learned" and "unlearned" – accurately represents its flavor. Gout of Silphium refers to "a taste of strong, nasty flavor." Garlic Venison, while perhaps a culinary delight to many meat-eaters, apparently had a wretchedness similar to Devil's Dung to Tull; he comments strongly against the taste of garlic elsewhere. The Mortified Venison, of course, would be disgusting to many tastes. –A.B. & M.C.

[108] Compost having been previously discussed at length, it is only required to say that if vegetable matter is allowed to mulch the crops, or is tilled into the soil, it indeed produces a superior manure than any animal product. –A.B. & M.C.

The use of animal bodies as manure is especially bad

If a catalogue were published of all the instances of the pestiferous effects that happen from the putrefaction of dead bodies after great battles, nobody (I believe) would have a good opinion of the wholesomeness of animal dung.[109]

Animal and human toxins make cities unhealthful, and foods grown with city manures are less healthful than country foods

In great cities the air is full of these toxins which, in hot climates, often produce pestilence. But even in cold climates, people are generally observed to live a less time and less healthfully in cities than in the country—the eating of unwholesome garden produce may contribute to this. Dung is a fitter food for venomous creatures[110] than for edible plants.

Vermin enjoy dunged gardens

Dunged gardens are more frequented by toads—and toads are seldom or never seen in the undunged fields.

Some have lost their lives by toads when they have accidentally boiled a toad in the leaves of a loaf-cabbage.[111] Others have died by being poisoned when the toads fixed their claws on an arm. A mountebank[112], to show the power of his antidotes, used to eat part of a toad on his stage and then cure himself by his medicine. I was told by one who saw the unfortunate mountebank after he ate too large of a dose of the poison (or perhaps delaying too long in the administration of the antidote). The mountebank's life was despaired of, though he later, with much difficulty and much time, did

[109] Animal dung: it is in this case not just the fermented animal waste, but the fermented animal. –A.B. & M.C.

[110] Mr. Evelyn says that "Dung is the Nurse of Vermin."

[111] We are inclined to believe that if a toad went unnoticed into the pot, any number of things could have gone unnoticed into the pot and it is impossible to say that a toad was responsible for the death of the unfortunate person (though it is impossible to discount the toad as the cause of death, too). Indeed, the "toad" in question might not have been a toad, having been misidentified. We believe, based on potential toxicity and its location in the leaves of a cabbage, that the culprit was actually a poisonous land mollusk or poisonous insect. However, the toxicity of toads is real, though mild (we and visitors to our farm have enjoyed holding toads with no problems whatsoever), and though it is unlikely that a toad would have lived in the leaves of a cabbage. –A.B. & M.C.

[112] "Mountebank" is a word that originally comes from the French montare (to mount) and banco (bench). The term was developed to describe a person who sells questionable medicines from a platform or another type of boastful pretender. Shakespeare adapted the word twenty-four years before the *Horse-Hoeing Husbandry* was written to describe the action of beguiling or transforming by trickery. –A.B. & M.C.

recover. So notwithstanding what some authors have said of the innoxiousness of toads, I am convinced that nature did not give most people an aversion to the toad without purpose.[113]

Roots grown in filth among vermin are unhealthful: plant bodies store toxins

What can we say then to the celebrity of those roots that are bred up and fattened among toads and other corruptions of dung? The leaves are only discharging some of the filth in which they grow, and when we eat the roots we have that unsavory infected food for our nourishment.[114]

As bad as dung is, it is necessary – except under Tullian agriculture!

But, though dung is, upon these and other accounts, injurious to the garden, it is such a considerable benefit to most fields of grain that without dung, little can be done...without the horse hoeing husbandry.

Acceptable use of dung in animal foods

Dung is not injurious to all fields. Such plants as cabbages, turnips, carrots and potatoes, when they are designed only for the fattening of cattle, will not be injured by dung: the cattle like them none the worse for the flavor. Indeed, tillage and hoeing together with dung make the crops the greater.

And it is fortunate that dung does not corrupt grain! Common tillage alone without dung is not sufficient for many sorts of grain, especially wheat[115].

Dung is expensive and unplentiful except near cities

Yet very few fields can have the convenience of a sufficient supply of dung to enable them to produce half the wheat that those fields will do that have plentiful supplies of dung because they are near cities.

Dung fermenting on the soil does not warm plants in winter so much as tillage

The action of the dung's fermentation affords warmth to the infant-plants in the common way of laying it on. But though dung in fermenting may be warm, because it lets water enter into its

[113] It may not be a mortal poison to every human body, though: I know of a man that has eaten several toads without any apparent injury. But, I believe that most who shall try the experiment of eating toads will be forced to confess that what is that one man's meat is another man's poison.

[114] In modern days, there is renewed concern that chemical fertilizers – and herbicides, pesticides and other toxins – are retained in plant tissues. –A.B. & M.C.

[115] It goes without saying that Tullian tillage without manure is more than sufficient for wheat. —A.B.&M.C.

hollows, during a frost dunged soil can become much colder than undunged soil—even when dung is well-rotted.[116]

I have seen wheat-plants in the winter die while in the very spits of dung while undunged drilled wheat, adjoining to it and planted at the same time, flourished all the through the same winter. I could not find any other reason for this contrast except the hollowness of the dung. But it is hard to know how long the warmth of the fermentation lasts by reason of the great difficulty to distinguish the very least degree of heat from the least degree of cold.

Artificial pasture better than dung

The difference in the quantity of artificial pasture made by dung without tillage and the amount which is made by tillage without dung favors tillage: an unplowed field, wherein a dunghill had lain for two or three years before being taken away, was planted with turnips. At the same time, a tilled field (contiguous thereto) was drilled with turnips and horse hoed. The first, being hand hoed and amply supplied with dung, prospered best in the beginning, but at last did not amount to the fifth part of the undunged and horse hoed land in bigness or in yield.

The benefit of the dung and hand hoe was inconsiderable in comparison to the benefit of the horse plow because the great quantity of artificial pasture given to the first land remained at the surface and did not reach deep enough to maintain the turnips until they had grown to the surface while the land without dung was provided with artificial pasture that reached to the bottom of the turnip roots.

Several lands of turnips, drilled on the level at three foot rows, plowed, doubly dunged and horse hoed did not produce near so good a crop of turnips planted on six foot rows and horse hoed did—even though the two lands were adjoining and the six foot horse hoed ridges had not been dunged for many years. There was no other difference between the lands than the width of the rows.

That the three foot rows prohibited the horse hoe to raise more than half the artificial pasture through tillage that the six foot rows did is as easily seen as how the dung, plowed into the narrow aisles before drilling, could operate not much further than the hoe-plow could.

I have made many trials of fine dung on the rows and notwithstanding the benefit of it, I have, for these several years past, left the dung off (having found that a little more hoeing does just as much good at much less expense than a small quantity of manure—with the hands and carriage to apply it—can do).

Dung can do very little without tillage. With some tillage, dung can do some good. With much tillage, dung pulverizes the soil in less time than tillage alone can do. But tillage alone, without dung, can pulverize the soil just as well as dung.

[116] Though more has been previously discussed on mulch, it bears being said again here that vegetable mulch keeps soil warmer, enhancing the effect of the horse-hoeing husbandry. Mulched soil can be worked earlier in the season and, especially after the dung is worked into the soil by the regular tillage, provides a much richer soil than unmulched soil affords. Such unfermented vegetable dung is as easily provided for by trees. We have observed that an unfermented vegetable mulch of only an inch or two prevents soil freezing. Also, by increasing porosity of the soil, Tullian husbandry improves the insulative capacity of soil, keeping it warmer in the winter and cooler in the summer. – A.B. & M.C.

Jethro Tull's Supplement

Aged manure less potent; aging manure is beneficial to flavor, but not to the Virgilian farmer's profits

But if the manure is thoroughly ventilated and putrefied before it be spread on the field (as I think all the authors I have read direct) so much of its salts will be spent in fermenting itself that little of them will remain to ferment the soil, and the farmer who might manure one acre in twenty by laying on his manure while fully replete with vigorous salts may (if he follow these writers' advice to a nicety) be forced to content himself with manureing one acre in a hundred.

This, indeed, is good advice for gardeners to make their stuff more palatable and wholesome, but would ruin the Virgilian farmer, who could have no more manure than what he could make upon his arable farm.

Let green or animal manure ferment in the ground

For every sort of manure, the longer time it ferments without the ground, the less time it has to ferment in it, and the weaker its ferment will be. [117]

Reason to ferment manure before application to the soil is to kill weed seeds; this is easier and more profitably done with Tullian hoeing. Yet, it is unnecessary to kill weed seeds if Equivocus and Virgil are correct in spontaneous generation – which they are not

The reason given for this great diminution of manure is that the seeds of weeds may be rotted and lose their vegetating faculty; but this would be of little purpose, if, according to the opinion of Equivocus, and the lowest degree of the Virgilian vulgar, weeds sprung up naturally from the soil by spontaneous generation.

This I am certain by demonstration: let a dunghill remain three years unmoved, though its bulk be vastly diminished in that time, and its best quality lost, charlock-seed will remain sound in it, and stock the land whereon it is laid. That ferment which is sufficient to consume the virtue of the stercoraceous salts is not sufficient to destroy the virtue of charlock-seeds, nor (I believe) of many other sorts of weeds.

Vegetable (green) manures are best for edible plants

But the manure of vegetables is much more wholesome for the use of edible roots and plants than that of animals is. [118]

[117] For this reason Fukuoka has his green manures decompose in the ground. Fukuoka even buries entire logs into the ground and lets them rot there. –A.B. & M.C.

[118] This Fukuoka and we agree with. We have found the best manure to be tree leaves: we leave them on the surface of the soil all winter, and then turn them under in the spring. This keeps the soil warmer in the winter, allowing the microorganisms to better fertilize it and provides shelter to the

The very effluvia of animal bodies, sent off by perspiration, are so noxious as to kill the animal that emits them if confined to receive them back in great quantity by breathing in an air replete with them. This was proven from the quick death of an animal shut up in a receiver full of air. Yet this seems to be most harmless of all the sorts of animal-excretements the air can be infected with. How noxious then must be the more fetid steams of ordure?

Animal manure required in very small amounts if at all; use what animal manure is produced as a byproduct of normal farm processes, but do not seek extra

I keep a team of horses for the use of a tile-kiln, which helps me at present to manure about ten acres annually. But if I retire them, as I intend, I shall not raise dung for above three acres.

And yet I have 120 acres of wheat every year, a hundred of them being drilled on the stubble of my last year's wheat-crop. If I have only manure for three acres in the old husbandry, good it is for me that manure is not necessary in the new husbandry.

Manure without tillage does little, tillage without manure does much, tillage and manure does most. Pulverization of soil is key, and requires the use of new tillage equipment, or different use of standard tillage equipment

Manure, without tillage, can do very little; with some tillage does something; and with much tillage pulverizes the soil in less time than tillage alone can do. But the tillage alone, with more time, can pulverize as well.

This the experiments of artificially pulverizing of the poorest land, as they are related by Mr. Evelyn, fully prove. And these experiments are the more to be depended on, as they are made, both in England and Holland, by persons of known integrity. This truth is also further confirmed by those authors who have found that highway dust alone is a manure preferable to manure. And all these pulverizations being made by attrition or contusion, why should not our instruments of pulverization in time reduce a sufficient part of the staple of a dry friable soil to a dust equal to that of a highway?

creatures we depend upon in the spring to defend our crops. This layer of leaves we lay down on the newly tilled aisles in the beginnings of autumn. –A.B. & M.C.

CHAPTER SIX:
OF TILLAGE

Definition of tillage: the breaking, dividing and aerating of the soil

Tillage is the breaking and dividing of soil by spade, plow, hoe or other instruments that break and divide soil by a sort of attrition, contusion or pulverization that is similar to how dung breaks and divides the ground in fermentation. "To till is nothing other than to break up and aerate the soil," says Columella.[119]

Tillage increases the artificial pasture of plants, and may be similarly undertaken by dung, plows, rollers and other instruments of agriculture; ants and worms undertake tillage as well; agriculture is necessary to the health of ecologies and may be seen as an improved pioneering strategy

The artificial pasture of plants is increased by pulverization.[120] This pulverization may occur equally well by the ferment of dung, the attrition of the plow, the contusion of the roller or by any other instrument or means whatsoever (except by fire, which carries away the soil that is burned).

[119] "Neque enim aliud est colore quam resolvere et fermentare terram," translation by Justin Walker.

[120] The natural pasture of plants, while scanty, is improved by disuse more than misuse. This is largely because humans are not the only ones who conduct tillage. Ants and worms move more earth than any other organisms—including humans. Worms and ants conduct activities nearly identical to tillage. The actions of these small organisms bring organic material into the soil (ants and worms will forage from great distances—even hundreds of feet), actively promote microorganic activity, and otherwise build and improve soil that is more hospitable to life. When humans and these small creatures work together, Charles Darwin noticed a more effective formation of soil:

> "Worms abound to an extraordinary degree in kitchen gardens where the soil is continually worked, though in such loose soil they generally deposit their castings in any open cavities or within their old burrows instead of on the surface. Von Hensen estimates that there are about twice as many worms in gardens as in corn-fields (*Zeitschrift für wissenschaft, Zoologie*, B. xxviii, 1877, p. 361)...
>
> Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They periodically expose the mould to the air, and sift it so that no stones larger than the particles which they can swallow are left in it. They mingle the whole intimately together, like a gardener also prepares fine soil for his choicest plants. In this state it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of nitrification. The bones of dead animals, the harder parts of insects, the shells of land-molluscs, leaves, twigs, &c., are before long all buried beneath the accumulated castings of worms, and are thus brought in a more or less decayed state within reach of the roots of plants. Worms likewise drag an infinite number of dead leaves and other parts of plants into their burrows, partly for the sake of plugging them up and partly as food.

> The leaves which are dragged into the burrows as food, after being torn into the finest shreds, partially digested, and saturated with the intestinal and urinary secretions, are commingled with much earth. This earth forms the dark-coloured, rich humus which almost everywhere covers the surface of the land with a fairly well-defined layer or mantle...
>
> When we behold a wide, turf-covered expanse, we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly leveled by worms. It is a marvelous reflection that the whole of the superficial mould over any such expanse has passed, and will again pass, every few years through the bodies of worms. The plough is one of the most ancient and most valuable off man's inventions; but long before he existed the land was in fact regularly ploughed, and still continues to be thus ploughed by earth-worms."
>
> —from the Introduction and Conclusion to *the Formation of Vegetable Mould Through the Action of Worms*, by Charles Darwin 1900, pages 4-5, 312-313, 316

If humanity does not till, the earth is moved by others, but humanity can move the earth with better skill (because of science like Tull's) than any other creature!

The combined efforts of Bert Holldobler and Edward O. Wilson have demonstrated that the actions of ants are similar to the actions of earthworms in their book, *the Ants* (1990). While ants move about as much soil as earthworms, their actions differ slightly. While both ants and worms aid the vegetation and revegetation of the landscape by transporting seed into their burrows, ants sometimes undertake a symbiosis with a plant to ensure its survival over its lifetime, helping the human significantly. Ants can perform their tillage-like actions in places the worms do not thrive in...even thriving under the effects of hard radiation or industrial pollution (even being able to outlive the other species of their environment). Ants have also been seen to pollinate flowers.

Ants domesticate animals, fungi and plants, and will protect them during fires and other disasters (worms typically hide during such disasters), ants will eliminate competing "weeds" from their domesticated plants, and generally undertake agriculture...often improving the yield for the human as the human improves the yield for the ant.

The ant's role, like the earthworm's and the human's, is a pioneering one: where ants and worms go, they prepare the land for other species. Earthworms, ants, humans and even other species actively improve the environment for their species and, in doing so, improve the environment for other species.

Human tillage is potentially better for the agroecology than earthworm or ant tillage because humans are able to *scientifically* undertake tillage on a larger scale, and are able to move the soil not only with their bodies (as even ants and worms can do), but domesticate horses, cattle, dogs, llamas, and other creatures to help them move the soil. Humans are able to then create technologies and develop skills to further improve their ability. Ants, earthworms and humans all can level mountains to make arable land, but the human can do so much faster and better than the ants or earthworms can. The Gaian hypothesis, already much discussed, relates the reasoning behind why agriculture would improve the pioneering processes of ecology.

The works of Charles Darwin, Bert Holldobler and Edward O. Wilson and James Lovelock are all strongly advised further reading. –A.B. and M.C.

Disadvantages of dung for increasing artificial pasture

But, in dividing the soil by dung, we are limited by the quantity of dung that we can procure (which, in most cases, is scanty)[121] while, by tillage, we can enlarge our field of subterranean pasture without limitation—even if the external surface of the field is confined within narrow bounds. Tillage extends the soil's internal surfaces in proportion to the degree of division and, because the possible division is infinite, so is the possible amount of surfaces!

Two or three plowings equate to a single dunging at less cost than a single dunging, up to 80% less

It is recently proved by the experience of many farmers that two or three additional plowings will supply the place of dung.[122] Both tillage and dung are beneficial to all sorts of land, but the hiring price of three plowings (after land has been thrice plowed before) is twelve shillings, whereas the cost of a dunging will be three Pounds.[123]

Effects of tillage include opening of new surfaces within the soil

Every time the soil is broken by tillage (or any sort of division), there must become open some new surfaces of those divisions that have never been opened before. In this way, there is a potential for fertility from the infinite division of the soil: once the parts of the soil are united and incorporated together, it is impossible that they should be broken again in the exact same place they were previously. In other words, tillage opens new surfaces within the soil because the inner surfaces of the soil will never have the exact same shape in the second breaking that they had in the first breaking. It is as likely that the soil should be broken in exactly the same place as the letters of a dictionary, if cut apart and mixed and then thrown up into the air, might fall into the same order and position with one another as they shared before they were broken and divided.

A preceding crop may, in this way, deplete the internal surfaces and, while the next plowing may move many of the before divided parts without breaking them, there will always be some surfaces that are newly broken.

[121] Limitations on the effectiveness of dung and other fertilizers are many, and even though there is little shortage in the amount of filth available for a farmer to put on their fields these days, the effectiveness of any fertilizer is limited by the effect of that fertilizer on the land itself: fertilizers can over-nitrify the soil, solidify the soil into a substance as hard as concrete by direct chemical action or the destruction of soil microorganisms or both, and harm plants in any number of ways. –A.B. and M.C.

[122] An impoverished farmer in my neighborhood had prepared his land for barley, but could not procure seed to sow it. He plowed it on until wheat seeding time and, by means of such additional plowing without dung, had a crop of wheat that was judged to be worth more than the inheritance of the land it grew upon.

[123] One Pound was worth 20 Shillings during the time of Tull: plowing saved 2 Pounds, 8 Shillings, or 80% of the costs of fertilization. A comparison of modern costs is presented in the chapter of the Differences between the Old and the New Husbandry and Modern Economic Analysis of the Tullian Agriculture. –A.B. & M.C.

Tillage of light, heavy and puffy soils makes them less light or heavy or puffy

Light land[124], being naturally hollow, has larger pores (which are the cause of its lightness). If light land is insufficiently divided, it will become lighter. But, light land, when it is by any means sufficiently divided, becomes heavier. Through division, the pores are brought nearer together[125] so that the same quantity of light land takes up less space. The light land, thus strengthened, then partakes of the nature and benefits of strong (heavier) land: the light land has become heavy land and will better keep out excessive heat and cold, etc.

Strong land[126], being naturally less porous, is made by sufficient division richer. Strong land is made lighter by tillage: the pores are separated to take up more room than they would in their natural state.[127] The heavy land, thus lightened, then partakes of the benefits of light land. But, when strong land is insufficiently divided (so that the parts remain gross and called "rough"), the strong land does not have the benefit because most of the artificial pores are too large: strong land insufficiently plowed partakes of the inconveniences of light land that has not been sufficiently tilled.

Plowing light land only once or twice is insufficient to diminish its natural hollowness (or pores) and, for want of more tillage, the parts into which it is divided by that once or twice plowing remain too large. By only once or twice plowing, the artificial pores are large and, in that respect, are like the ill tilled strong land. Light land, having naturally fewer internal surfaces, seems to require more tillage or dung to enrich it than heavy land.

As for puffy land (which naturally swells up instead of subsiding), though its lightness is much abated by tillage, it is typically thought little better than barren land and unprofitable for corn. Indeed, puffy land becomes so much lighter by being ill tilled (the pieces of unbroken turf remain underneath undissolved, forming large cavities that increase the porosity of the soil) that I have often known this sort of land despised by its owners, who feared to give it due tillage: they thought that the tillage would make it so light that the wind would blow it away! But whenever puffy land has been sufficiently tilled, it never failed to become much stronger than it was before, and considering that it is tilled with less expense than very strong land, it is, for several sorts of corn, found to be more profitable than land of greater strength and richness that is more difficult to be tilled.

Land can be too hollow and light that has no cement to join its parts together. Such too-light land is in theory capable of infinite division, but the plow cannot divide it to any purpose in practice. The plow glides through the too-light land without breaking it; it is like pulling the plow through water. The too-light land may be moved—but not broken—by tillage, and therefore ought not to be

[124] Read "light land," understand "sandy" for most situations – exceptions would exist. –A.B. & M.C.

[125] While tillage helps directly in this process, tillage also helps indirectly by encouraging the microorganisms that bind the soil together in the creation of humus. Tull touches upon this, calling the humus the "cement" of the soil, both in this section and elsewhere. –A.B. & M.C.

[126] Read "heavy land," understand "clayey" or "silty" for most situations – exceptions would exist. –A.B. & M.C.

[127] While tillage helps directly in this process, tillage also helps indirectly by encouraging the microorganisms that prevent the soil from coming too close together in the creation of humus. –A.B. & M.C.

reputed arable; nor does it indeed deserve the name of "land" any more than the desert sands of Libya are called land to distinguish them from "sea."

Natural pores are too small and too hard; insufficient tillage on strong land results in natural pores too small and artificial pores too large; insufficient tillage on light land results in all pores too large. Roots eat by the pressure of the ground against them, and pores too large do not allow them to feed while risking damages from the atmosphere; pores too small and hard do not allow roots to enter into them

Natural pores are generally too small and too hard for the entrance of weaker roots. Insufficient tillage leaves strong land with its natural pores too small and its artificial ones too large; insufficient tillage leaves light land, with its natural and artificial pores too large.

Pores that are too small in hard ground will not easily permit roots to enter them. Pores that are too large in any sort of land can be of little other use to roots except to give them passage to other cavities that are more proper for them. And, if in any place the pore lies open to the air, the pore will easily dry up and spoil the root before it reaches a better cavity: pores dispense their food to the lacteals of the fibrous roots by pressure only.

If the fibrous roots cannot press against the surfaces of a cavity, they cannot maintain the plant: fibrous roots are the only roots that maintain the plant. The larger roots serve the plant by receiving the juices from the fibrous roots for conveyance to the stem. A pore whose diameter is greater than that of the fibrous root is difficult for the fibrous root to gain food from.

Tillage should make land fine (or pulverized)

The more fine (or pulverized) land is made by tillage, the richer it will become and the more plants it will maintain.

It has been observed that when part of a ground has been better tilled than the rest, afterwards for more than six years the part that was but once better tilled always produced a better crop than the rest.

Penetration and condensation of dew increases soil water if land is well tilled, if insufficiently tilled, the soil will release moisture and become drier; transpiration of water by crops increases the dew point and encourages precipitation and condensation

When soil is made finer, the dews are able to penetrate within and beyond the surface to the roots; once being made finer, the roots are better able to enter to where the dews have penetrated

Rough tillage with large clods will not allow dews to condense within the soil and will not increase soil water capacity

The rough large clods cannot have the same benefit from the dews: the dews are not able to enter them any better than the roots. *Minus habentibus minus datur, et vice versa.*[128]

If the clods from plowing are too large, they act as sinks to convey what rain and dew bring too quickly downwards to below the plowed part.[129]

The first and second plowing with common plows are not tillage, but do prepare the soil for tillage; the third, fourth and subsequent plowings are of more benefit and less expense than the first two

The first and second plowings, with common plows, scarce deserve the name of "tillage," they rather serve to prepare the land for tillage. The third, fourth, and every subsequent plowing may be of more benefit and less expense than any of the preceding ones.

Later tillage best accomplished by hoeing, to be discussed in the following chapter

But the last plowings will be more advantageously performed by way of hoeing, as in the following chapter will appear.

Confirmation by Mr. Evelyn

I think nothing can be said more strongly to confirm the truth of this than what is related by the authors quoted by Mr. Evelyn in pages 17-19 of his *Phil. Discourse of Earth*: "take of the most barren Earth you can find, Pulverize it well, and expose it abroad for a Year incessantly agitated[130], it will become so fertile, as to receive an Exotic Plant, from the furthest Indies[131]; and to cause all Vegetables to prosper in the most exalted degree, and to bear their Fruit as kindly with us, as in their natural Climates."

This artificial dust[132], he says, will entertain plants that refuse dung and other violent applications. And this artificial dust has a more nutritive power than any artificial dung or composts whatsoever! And he says that by this toil of pulverizing, "tis found, that Soil may be so strangely

[128] This is translated by Justin Walker: "less is given to those having (or possessing) less, and vice versa", i.e. more is given to those having (or possessing) more.

[129] The leaching of nitrate nitrogen and other nutrients is "clearly dependent on drain flow," and so the more fine the soil is, the less leaching will occur because there is "less pore continuity" and fewer "vertically-oriented pores" (Goss, M.J., et. al. Losses of Nitrate Nitrogen in water draining from under autumn-sown crops established by direct drilling or mouldboard ploughing: Canadian Journal of Soil Science, 1993, volume 44, pages 35-48). –A.B. & M.C.

[130] i.e. stirred often.

[131] Is it to be supposed that if Indian plants had their due degrees of heat and moisture given them, I would not need to bestow this toil upon the poorest of earth, in field or garden? I believe Indian plants should do better with finer, tilled soil, but am unable to make the experiment.

[132] Though it may be impossible for the plow to reduce the whole staple into so fine powder, the more internal surfaces it makes, the more dust will be deposited by the atmosphere in proportion. Large clods are of no use to plants.

alter'd from its former Nature, as to render the harsh and most uncivil Clay[133], obsequious to the Husbandman, and to bring forth Roots and Plants, which otherwise require the lightest and hollowest Mould."

To this dust the doctrine of "*namque hoc imitamur arando*[134]" ought to be applied, and not to the "*putree solum*[135]" (which itself needs tillage as much as strong land). Yet it seems the ancients did not observe the difference between natural pores (or hollowness) and artificial ones (though it is very great, as is shown in the Chapter of the Pasture of Plants). I never myself tried this way of pounding or grinding, because it was impracticable in the fields.

Tillage improves crop yield; soil can never suffer from too much tillage

I am in no doubt that any soil (be it rich or poor) can ever be made too fine by tillage. One cubical foot of this minute powder may have more internal surfaces than a thousand cubical feet of the same (or any other earth) tilled in the common manner. And, I believe, no two arable earths in the world exceed one another in their natural richness twenty times (that is to say, in their natural richness, one cubical foot of the richest is not able to produce an equal quantity of vegetables, *caeteris paribus*, to twenty cubical feet of the poorest).

Poor land can be made into rich land if well pulverized because the plants are well nourished: they have ample food and may eat it with ease with more mouths

Is it not then remarkable that the poorest land should, after being pulverized, obtain one hundred times the internal surfaces of the rich untilled land and exceed the rich land's fertility by the same proportion? Is it also not remarkable that, should a foot of the poorest be made to have twenty times the surfaces of a foot of such rich land, the poorest might produce a greater quantity of vegetables than the rich?

Very poor land, well pulverized, will produce better corn than very rich land will do without manure or tillage. The experiment may be made by paring off the turf and setting corn in the whole ground that is very rich. The yield of that corn, when compared to the yield of well pulverized very poor land, will show how much the natural pasture of the rich is inferior to the artificial pasture of the poor land.

When a soil has a large number of internal surfaces in a very small area, the roots of plants in it are better supplied with nourishment because the nutrients are nearer to them on all sides. In common tillage, the roots must extend much further than with the new tillage to reach an equal quantity of nourishment: they must range and fill perhaps above twenty times more space to collect the same quantity of food. In fine soil, the most weak and tender roots have free passage to the

[133] But I take "harsh uncivil clay" to be the least profitable soil of any to keep in tillage.

[134] This is translated by Justin Walker: "for we imitate this by plowing." It refers to the Virgilian perception that all tillage attempts to recreate the "crumbly or powdery soil" through "imitation." —A.B & M.C.

[135] This is translated by Justin Walker: "crumbly or powdery soil." It refers to the Virgilian belief in "taking it easy," or choosing land already in tilth. –A.B. & M.C.

utmost of their extent. When a soil has a large number of internal surfaces in a very small area, roots enjoy easy, beneficial and equal pressure everywhere, as in water.

Hard ground makes a too great resistance, as air makes a too little resistance, to the surfaces of roots.

Common errors in tillage: not tilling enough, rolling (tamping or compressing) clods or newly-planted seeds

Columella wrote, "the ancient Romans said a field was poorly prepared when it had to be harrowed after the crop was in the ground."[136] Farmers, just when they have brought their land into a condition fit to be further tilled to much greater advantage, leave off, supposing the soil to be fine enough when, with the help of harrows, they can cover the seed; afterwards multiply the error by compressing the ground with a roller: they break the clods (so that, if their crop succeeds, they may be able to mow it without being hindered by those clods).

This instrument, called a roller, is seldom beneficial to good husbands: it rather untills the land, and anticipates and brings about the subsiding of the ground—which in strong land happens all too soon anyway.

This injury the roller does only when it is used to press down the earth after the seed is sown (and causes more injury if land is moist). But here is how it is seldom useful to good husbands: rolling in dry weather, when the soil is to be immediately plowed up again, is the most speedy way to pulverize the soil's clods.

But more to blame than those who would roll their soil are those who neglect to give their land due plowing entirely, trusting to the harrow to make it fine: when they have thrown in their seed, they go over it twenty times with the harrows until the horses have trodden it almost as hard as a highway[137].

Jethro Tull's Supplement: Soil is Warmer in Summer

Water in wells and springs is not warmer in winter than in summer; it only seems to be so because our sense of feeling is differently affected by touching it, as our hands and the air are colder in winter than in summer, to a greater degree than subterraneous water is.

For want of taking notice of that vulgar mistake, Equivocus asserts, that soil is warmer in winter than in summer.

[136] "Nam verteres Romani dixtrunt male subactum agrum qui satis frugibus occundus sit. Sed ut compluribus iteractionibus sic resolvatur vervactum in pulverum, ut nullam vel exiguam desideret occationem cum seminaverimus." –Col. Lib. 2, Cap. 4. Translation from Harrison Boyd Ash's book, *Lucius Junius moderatus Columella On Agriculture*, published in 1940 by Harvard University Press in Cambridge, Massachusetts.

[137] Horses, when the earth is moist, ought to tread in the furrows only, as in plowing with a horse plow they always do when they use it instead of a common plow. [And A.B. & M.C. add that tractor implements ought always be as wide or wider than the wheels].

Supplement of the Fifth Edition

Dew is a Good Source of Soil Water

It is one of the more shocking facts of Tullian tillage that it increases both soil water holding capacity and soil water. The formation of humus is the principle means by which Tullian tillage increases soil water holding capacity and has already been discussed at length in previous chapters: humus both increases the amount of precipitation accepted and held by the soil. The condensation of dew is another means by which soil water is increased.

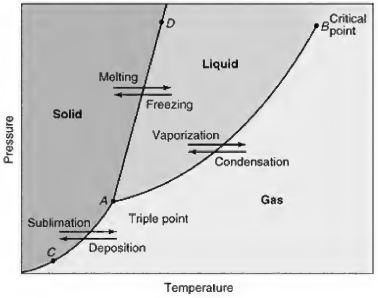
Condensation occurs often in nature and is a fairly simple process:

When matter expands, it cools its surroundings. Thus, when water evaporates off of skin, expanding from a liquid to a vapor, it cools the skin; when water evaporates out of the ground, it cools the surrounding air. The opposite is true as well: when the environment is warm, matter tends to expand. Thus, when the farm environment is warm during the day, soil water tends to evaporate, and when it is cool at night, water tends to condense.

The increased humidity produced by the evaporation of soil moisture increases dew point (the point at which condensation occurs), making the condensation of dew more likely: when the temperature drops below the dew point, condensation of dew will occur, and the overnight low temperature will be limited because the water, condensing from vapor to liquid, warms its surroundings. This is why the daytime and nighttime temperatures of a desert and a wetland of the same latitude will be so different (say, the difference between Tucson, Arizona and New Orleans, Louisiana).

There is thus a strong correlation between precipitation and soil moisture: if moisture is in the air due to evaporation, low pressure weather systems will condense their moisture and precipitation will occur. If soil is dry, there is less likelihood of rain. Life, which increases soil moisture content through the production of humus, encourages the precipitation and condensation it needs to make more humus.

Besides increasing the likelihood of dew by increasing the water holding capacity of the soil, Tullian tillage creates pores that have a different pressure than the atmosphere and the soil that surrounds it. The graph below illustrates the reactions of gasses, liquids and solids to changes in pressure and temperature.

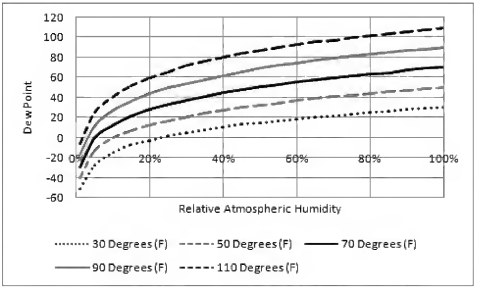


Increasing temperature brings solids to become liquids, and liquids to become gasses; increasing pressure on the matter performs the opposite.

Water vapor will condense when the pressure of an atmosphere increases, when a surface is colder than the dew point.

	Dew Point Temperature at				
Relative Atmospheric Humidity	30 Degrees (F)	50 Degrees (F)	70 Degrees (F)	90 Degrees (F)	110 Degrees (F)
1%	-51	-40	-29	-17	-6
5%	-27	-13	0	12	25
10%	-15	0	13	27	41
15%	-7	7	22	36	52
20%	-3	13	28	44	60
25%	2	17	33	50	66
30%	5	21	37	54	72
35%	8	24	41	58	76
40%	11	27	45	62	80
45%	14	30	48	66	84
50%	15	32	51	69	87
55%	17	34	53	72	90
60%	19	37	56	74	93
65%	21	39	58	77	96
70%	22	41	60	79	97
75%	23	42	62	81	100
80%	25	44	64	83	102
85%	26	46	65	85	104
90%	28	47	67	87	106
95%	29	49	69	88	108
100%	30	50	70	90	110

Calculations based on perfect gas relations published in 1989 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Fundamentals Handbook. http://www.ashrae.org/ and Sugar Tech, a Zambian Society of Sugar Engineers (http://www.sugartech.co.za/psychro/index.php)



The small pores created by Tullian tillage maintain a fairly constant pressure and in the morning, when the air warms and the soil air does not (as quickly – the pores are insulated by soil and humus), atmospheric water vapor condenses onto and into the soil. While the soil then exhales moisture in the evening as things cool and the pressure drops, the water vapor in the pores condenses on the surfaces of the pores and can be drunk by roots and microorganisms. The transpiration of the plants as they use this water is what, in healthy and Tullian soils, leads to an increase in dew point; in unhealthy and conventionally-tilled or untilled soils, the soil water vapor escapes directly to the atmosphere without any hindrance and raises the dew point.

	Ounces of Condensed Water per Cubic Foot of Air at				
Relative Atmospheric Humidity	30 Degrees (F)	50 Degrees (F)	70 Degrees (F)	90 Degrees (F)	110 Degrees (F)
1%	0.0595	0.1030	0.1495	0.1991	0.2517
5%	0.2975	0.5149	0.7475	0.9954	1.2586
10%	0.5950	1.0298	1.4951	1.9909	2.5172
15%	0.8925	1.5446	2.2426	2.9863	3.7758
20%	1.1899	2.0595	2.9901	3.9817	5.0344
25%	1.4874	2.5744	3.7376	4.9772	6.2930
30%	1.7849	3.0893	4.4852	5.9726	7.5516
35%	2.0824	3.6042	5.2327	6.9680	8.8101
40%	2.3799	4.1190	5.9802	7.9635	10.0687
45%	2.6774	4.6339	6.7278	8.9589	11.3273
50%	2.9749	5.1488	7.4753	9.9543	12.5859
55%	3.2723	5.6637	8.2228	10.9498	13.8445
60%	3.5698	6.1785	8.9703	11.9452	15.1031
65%	3.8673	6.6934	9.7179	12.9406	16.3617
70%	4.1648	7.2083	10.4654	13.9361	17.6203
75%	4.4623	7.7232	11.2129	14.9315	18.8789
80%	4.7598	8.2381	11.9604	15.9269	20.1375
85%	5.0573	8.7529	12.7080	16.9224	21.3961
90%	5.3547	9.2678	13.4555	17.9178	22.6547
95%	5.6522	9.7827	14.2030	18.9132	23.9133
100%	5.9497	10.2976	14.9506	19.9086	25.1719

Calculations based on perfect gas relations published in 1989 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Fundamentals Handbook. http://www.ashrae.org/ and Sugar Tech, a Zambian Society of Sugar Engineers (http://www.sugartech.co.za/psychro/index.php)

How much dew is deposited in a soil? It depends on the atmospheric water and the temperature, but even a modest quarter ounce of condensed water per cubic foot of air in the atmosphere 1 foot above the surface of the ground would result in about 85 gallons of water per acre per dew. A full ounce of condensed water per cubic foot of air in the atmosphere 1 foot above the surface of the ground would result in 340 gallons of water per acre per dew.

In a desert, 10 ounces of condensed water per cubic foot of air in the atmosphere 1 foot above the surface of the ground would result in about 3,403 ounces (26.6 gallons) of water per acre of dew.

And, when it is considered that it is not just the atmosphere 1 foot above the surface of the ground that is depositing dew, the quantity of dew deposition can become considerable. The 26.6 gallons per acre can easily become hundreds of gallons if more than the first foot of atmosphere above the ground condenses. Just 200 gallons per acre applies to the soil 0.25 acre inches of water!

Condensation of Atmosphere as an Irrigation Source

An interesting application of this beyond making water available directly in the soil is the condensation of atmospheric water for irrigation use.

A structure can be made either of thin sheet metal or plastic whose interior could be cooled to facilitate the condensation of atmospheric water, or of walls forming a narrow compartment can be cooled so that the surfaces of the chamber walls facilitate the condensation of atmospheric water. The water can be carried by channels to cisterns or storage tanks.

Cooling is easily done either through the compression of air (inside the structure or by forcing condensed air into the structure from the outside through an "air conditioning" unit), and these compressors can be powered through solar electricity.

A building measuring 100 feet long, 10 feet wide and 10 feet tall would have 20,000 square feet of surface area, and in a desert where there is only 10% atmospheric water (at an average air temperature of 70 degrees) would be able to condense 1.5 ounces of water per foot of atmosphere, a total of 234 gallons, if only one cubic foot of atmosphere was condensed per square foot of surface area.

The rate at which water is condensed – the rate at which atmospheric water is converted to condensed water – is dependent on more factors than temperature and re-evaporation of the condensed water should be examined under the exact conditions of the farm. Experiments made to scale will yield excellent data, and the desert farmer is encouraged to undertake their own trials – or at least till their fields. However, the potential source of water is hard to ignore, and improvements to the structure to reduce re-evaporation (such as fabrics and other insulation against wind, fans to bring more atmosphere into contact with the structure, etc.) may be warranted if water cannot be more easily trucked in.

Desalinization of Ocean Water Feasible

If a source of ocean water is available near to the desert, the evaporation and then condensation of the ocean water would purify it, and provide plentiful desalinated water for agricultural purposes. This can be done by boiling the water, or even by allowing the sun to evaporate the water in a barrel, and capturing the condensation. The vaporization of water is a simple matter, and capturing water vapor as it rises from its source also requires little mastery, but the exact method of capture will depend greatly on the farmer's individual budget and material availability.

Even putting a plastic bag over leaves of a tree as it photosynthesizes will capture the vaporized water from the transpiration! The desalinization of ocean water is less difficult than the condensation of atmospheric water.

CHAPTER SEVEN:
OF HOEING

Definition of hoeing: tillage while plants are growing in the soil

Hoeing is the breaking or dividing of soil by tillage while the plants are growing in the soil. Hoeing differs from common tillage in the time of performance: common tillage is always performed before plants are sown or planted.

Definition of deep and shallow hoeing: deep ("horse hoeing") is used in aisles, shallow ("hand hoeing" or "scratch hoeing") is used in rows

Hoeing may be further divided into deep (which is the "horse hoeing" this book is named for), shallow (which is "hand hoeing") and shallow horse hoeing (used in narrow—sixteen or eighteen inch—aisles between rows. The shallow horse hoeing is an imitation of the hand hoe). Hand hoeing and shallow horse hoeing may be properly called "scratch hoeing" (for it is more like scratching and scraping than hoeing) and can neither supply the purpose of dung nor fallow.

Tillage, manure and hoeing is like chewing, salivating and digesting

Nature, by what she does in the animal body, seems to demonstrate something like hoeing: plows (as teeth) till soil (or food mass) while other soil preparation (including irrigation or manure) serves as saliva to prepare the food in the stomach (which digests the food into ingestible particles), then (as a thing of greatest benefit) the bile and pancreas are employed to further divide and open the food (as a plow were to hoe soil) at the very time when it is ready to be ingested by the greatest numbers of lacteal mouths situated in the intestines (or roots).

A plant is almost as imperfectly nourished by tillage without hoeing as an animal body would be without gall and pancreatic juice: roots pass along the soil as food passes along the guts.[138]

The more land is hoed the more it will produce; refutation of Dr. Warkentin's modern criticism of Tullian agriculture, especially of Dr. Warkentin's research methods: Nitrogen content in soil is stabilized through tillage, and tillage is a better option for improving soil fertility than Nitrogen fertilizers

Hoeing is much more beneficial than common tillage, and is performed by different instruments. The more a land is tilled, the more a land will produce.[139]

[138] Except in animals the gut is stationary and the food is passed along, while roots pass along soil. –A.B. & M.C.

[139] Dr. B. P. Warkentin, of Oregon State University in Corvallis, wrote a review of Jethro Tull's *Horse Hoeing Husbandry* in his *Tillage for Soil Fertility Before Fertilizers*, published in the Canadian Journal of Soil Science (2000, volume 8, number 3, pages 391-393). In his review, Warkentin mentions some of the benefits of tillage (namely, the loosening of the soil for roots, the pulverization of the soil to

ease plant grazing, the savings from good soil maintenance, etc.), but concludes that "Crop production today has ready sources of combined nitrogen. It is easy to forget about the amount of nitrogen coming from organic matter because it is a small part of the requirement for high yield cereals. The concern is more often with limiting the amount of nitrate in soils, and with decreasing carbon release, so extra tillage is a detriment. But in Tull's time, modifying the physical properties of the soil was a reasonable way to enhance soil fertility."

Warkentin would seem to believe that the horse hoeing husbandry is made obsolete by the availability of ready sources of combined Nitrogen while at the same time saying that extra nitrogen is a detriment. We will pass on debating the obsolescence of tillage in the face of a detrimental chemical, and instead urge Dr. Warkentin to either pick up a standard and basic soil chemistry text that describes the formation and dynamics of humus (as was reviewed in the first chapter of this book), or read the excellent article by Goss, et al. *which Warkentin cited* to understand that tillage helps moderate the amount of nitrogen in the soil by improving drainage:

> "Tillage had little effect on the amount of nitrogen lost in surface-layer flow (i.e. in combined surface runoff and interflow). But less nitrate-N was lost annually through the mole-and-pipe drainage system of direct-drilled land than of ploughed plots, so surface-layer flow represented a larger proportion of the loss under direct drilling...
>
> The greater continuity of vertically-oriented pores [in plowed plots—A.B. & M.C.] also explains the greater leaching of fertilizer nitrogen in spring from the direct-drilled plots (Goss *et al.*, 1988). This nitrogen would be close to the soil surface and easily transported in rainwater which would move laterally to macropores and then downwards in saturated flow. This may explain the greater application of nitrogen often required to achieve heavy yields when crops are direct drilled (see review by Cannell, 1985).
>
> In this experiment *reducing tillage consistently decreased the annual loss of nitrogen by leaching* [our italics – A.B. & M.C.] despite the greater loss that could occur in spring. Furthermore the decrease in loss by leaching was associated with smaller concentrations of nitrate in the drainage water. Contrasting differences in nitrate-N leaching between conventional tillage and direct drilling (zero tillage), depending on whether fertilizer had been recently applied, have also been described by Gilliam and Hoyt (1987).
>
> Farmers have a limited ability to control nitrate leaching from arable land under autumn-sown crops. Abandoning the application of nitrogen to the seedbed of autumn-sown crops would make the largest contribution to reducing leaching loss. The widespread adoption of direct drilling could also result in a further reduction."
>
> —MJ Goss, et. al. *Losses of Nitrate Nitrogen in water draining from under autumn-sown crops established by direct drilling or mouldboard ploughing: Canadian Journal of Soil Science*, 1993, volume 44, pages 35-48

If Dr. Warkentin is so worried about a buildup of Nitrogen, he should have read Dr. Goss's fine work and adopt a tillage system like Tull's.

What treachery! If an unwary farmer who had too much Nitrogen (as Dr. Warkentin is certain they do) and listened to the bad advice of Dr. Warkentin and not till, their Nitrogen would increase! If only the farmer had, instead, tilled, they would have developed pore structures to facilitate

leaching of Nitrogen while constructing the humus needed to *stabilize* the Nitrogen content in the soil.

What is a farmer to do, but trust their scientific leaders? There is one option, at least! By conducting their own trials, the farmer could learn that tillage does not lead to an excess of Nitrogen in the soil, but instead allows a general improvement to the soil every year through the development of humus, allowing the soil to become insulated against all extremes—including wetness, dryness, heat, cold and an extreme shortage or excess of nitrogen.

Dr. Warkentin should be relieved of his worries concerning Nitrogen build-up in the soil. And his worries about carbon release: thank goodness he cited his sources, or we would not have been able to read them to learn that he misrepresents them.

It is an atrocity beyond words: Dr. Warkentin holds a title few are worthy of, and abuses the trust of the public in both his Doctorate and the institutions that accredited him. The honor of his title none of the current or past editors of the Horse Hoeing Husbandry have earned; it is a shame to so carelessly spoil it.

It is so simple a thing for someone without a doctorate in soil science to conduct their own trials and research that Warkentin cannot justify his unfamiliarity with soil science—the very subject he professes at Oregon State University.

Some who reviewed this work before its publication say that this review of Warkentin's work is not fair, that we are too harsh on the Doctor, that we should not say he does not understand soil science. Yet we have been very generous with him: we wrote to Warkentin to ask clarification on his conclusions and addressed to him the concerns just described. Questions, arguments and assertions were posed. In his defense he avoids many of the questions posed to him. While this may be thought to be due to there being no adequate answer to them, an excerpt from his response presents an unanticipated alternative explanation as to why he is reluctant to respond to a reader's questions:

> "Tillage is a complicated process, among other things it changes pore size distribution, managing root contact with soil and decomposition dynamics, etc. Practitioners know about these things from their experiences. They walk on the soil. I do not study these areas...Tillage as such is beyond my fields of study in soil science."
>
> —Excerpt from Dr. Warkentin's defense

If only Warkentin had been so cautious when writing his article, he would not have said so much fraudulent nonsense! Perhaps if he had watched his steps on the ground he walked on he would have noticed not the wholesome humus of a well-tilled field, but the quicksand of ignorance.

Dr. Warkentin, in betraying the public's trust, sows bitter fruit and blights the progress of science. Yet so it has been, even since Jethro Tull's time, that farmers must take precautions to discover for themselves how to improve their agriculture:

> "Every man is best satisfied with experiments made by himself; therefore I advise him who intends to practice that he would repeat all my trials before he relies upon them—not because I have been unfaithful in the making or relating of any of my experiments (for I only made them in search of the Truth for my own satisfaction): I do not doubt that, if the reader

The benefits of hoeing are soon undone by the natural compaction of the soil

As soon as the plowman has done his work of plowing and harrowing, the soil begins to undo it: little by little, the soil inclines towards and endeavors to regain its natural specific gravity. The broken parts, little by little, coalesce, unite, and lose some of their surfaces. Many of the pores and inner surfaces close up before the seed has incubated and hatched within the ground.

Effects of compaction unmitigated by hoeing: the starvation of plants: their need for food increases as their available food decreases

Pity the seeds! As the plants grow up, they require an increase of food (proportional to their increasing bulk). Without hoeing, instead of their pasture increasing as their need increases, their pasture generally decreases. A maintenance or increase of pasture as the plants require it should be regarded as the most important benefit of hoeing.

The Earth is so unjust and cruel to plants (her own offspring!) as to shut up her stores in proportion to their wants, giving them less when they need more. Therefore humanity, for whose use plants are chiefly designed, ought to bring science to aid their relief, and force open the Earth's magazines with the hoe. This will procure for the plants at all times provisions in abundance while simultaneously freeing them from their spurious kindred, the weeds, which would rob them of their too scanty allowance.

Well tilled land has few weeds

follows the same process, their experiments will succeed as mine did. But by repeating the trials he may very likely draw many more lessons from them than I have."

—Jethro Tull, introduction to *the Horse Hoeing Husbandry*.

Agriculturalists must be scientists and scientists must be linguists if they are to dig deeper than those who lived before them by learning from those who live in distant countries where the language is different; Columella did not lie when he said that those who would practice agriculture well should be well practiced in many arts!

Reality defies Warkentin's conclusion that extra tillage is a detriment or is no longer a reasonable way to enhance soil fertility. Besides nitrogen, the balanced nutrition and humus tillage provides, the service to the roots Tullian tillage provides, remains the best recourse of a farmer seeking their self-betterment.

Tillage improves fertility while at the same time enabling the plants to consume more food by cutting their roots. "Modifying the physical properties of soil" is still as reasonable of a way to enhance long-term soil fertility as it was in Tull's time—even though combined nitrogen is widely available now, it is a more costly long-term maintenance of the soil than tillage and which has a lower return in terms of fertility than tillage does – as will be shown in the Chapter that compares the old and new husbandries, and provides modern economic analysis where, against reasonable belief, Warkentin's folly of not reading cited sources is learned to extend also to his inability to decipher Jethro Tull's excellent English. –A.B. & M.C.

Land that is tilled well before sowing will have few weeds. Weeds will come in along with the crop and will enjoy benefit of the tillage (greater or less, according to their number and their species) in land that is not tilled very much after sowing.

Manure should be applied both at planting and later in the season

The benefits of hoeing are improved, like tillage and manure, by application at the proper seasons: as manure should not only be applied at the time of sowing, so should tillage be applied not only at the time of sowing. It is as unreasonable to till or apply manure only in the spring as it would be to give triple the amount of leaves necessary to maintain silk worms upon their hatching and no more afterwards.

Transplanting is similar to hoeing, but damages the plant; taproots transplant least well; roots may be cut during hoeing within an inch of the plant for many plants

A process much like hoeing is transplanting, but transplanting is much inferior to hoeing because it requires a so much greater number of hands and because of the danger of moving a whole plant. Additionally, if the plant is not grown in a container, there is a loss of time before the plant can take root again (all the former roots having been broken off at the ends in the taking up) because the plant must wait until by the strength of its own sap (which is, by continual perspiration, daily enfeebled) new roots are formed. Unless the earth continues to be moist, these new roots are so long in forming that they not only find a more difficult reception into the closing pores, but many times the plant languishes and tragically dies of hunger or thirst, being starved in the midst of plenty. While a transplant slowly dies, a hoed plant obtains a more flourishing state than ever, without being removed from the same soil that produced it.

It has been observed that some plants are worse for transplanting than others. Most long tap-rooted plants are, for I have often tried the transplanting of plants. I have tried transplanting sanfoin and alfalfa, but I have never found that any transplanted tap-rooted plant does so well as those which are not moved. Funochio, when transplanted, is never so good and tender to eat as funochio that is not: the plant receives such a check in transplanting in its infancy that, like rickets, leaves knots that indurate the parts of the fennel and spoil it from being a dainty.

Hoeing has most of the benefits without any of the inconveniences of transplanting because it removes roots from the plant little by little and at different times. Hoeing ensures that some of the roots remain undisturbed so that they may supply the disturbed roots with moisture and the whole plant with nourishment sufficient to keep it from fainting until the new roots can enjoy the benefit of the new pasture (which is, by the aid of the unbroken roots, very soon).[140]

[140] This is a very important part of Mr. Jethro Tull's method, and derives from his experiments with mint. Hoeing among the established plants not only enables them to forage easier in more plentiful pasture, but at the same time gives them more lacteals to forage with. The editors have repeated Mr. Tull's experiments and found that the roots may be cut even to within an inch of the plant for many plants. –A.B. & M.C.

Hoeing reduces water needs of plants, reduces flooding, reduces drought; makes soil easy to work

Plants that are better nourished by hoeing require less moisture. This is confirmed by Dr. Woodward's experiment, that those plants which receive the greatest increase, having most terrestrial nourishment, carry off the least water in proportion to their augmentation. So do barley and oats, being sown on a part of a ground very well divided by dung and tillage, come up and grow vigorously without rain, even when the same grains sown at the same time on the other part not thus enriched scarcely come up (or, if they do, they will not thrive until the rain comes).

Proper hoeing keeps plants moist in dry weather[141]. The horse hoe procures moisture to the roots from the dews, which fall most in dry weather. Those dews (by what Mr. Thomas Henshaw has observed) seem to be the richest present the atmosphere gives to the earth, "Having, when putrify'd in a Vessel, a black Sediment like Mud at the Bottom." Mr. Henshaw suggests that dews seem to cause the darkish color to the upper part of the ground[142], and that the sulfur, which is found in the sediment of the dew, may be the chief ingredient of the cement of the earth (sulfur being very glutinous, as nitrogen is dissolvent). These and other chemicals enter in proportion to the fineness and freshness of the soil, which is made in proportion to the amount of hoeing.

Experiments proving that dews will moisten the field

To demonstrate that dews moisten the land when fine, dig a hole in the hard dry ground, in the driest weather, as deep as the plow ought to reach: beat the earth very fine, and fill the hole therewith. After a few nights' dews, you'll find this fine earth become moist at the bottom and the hard ground all round will continue dry.

These experiments will show how it is in our own power to make dry become wet instead of wishing them to be so and proves that the Virgilian theory (*Lest this scanty moisture/sap leave the sterile sand/desert*)[143] is directly contrary to the truth. Till a field in two lands, make one land very fine by frequent deep plowings, and let another be rough by insufficient tillage; then plow the whole field cross-ways in the driest weather and you will perceive, by the color of the earth, that every fine land will be turned up moist and every rough land will be dry as powder, from top to bottom.

[141] And dry in wet weather: tillage causes the soil to become highly insulated against heat, cold, moisture and dryness. While Tull is not incorrect in saying that the dews are allowed into the soil, it is the soil composition, being changed by the increase in organic matter (dead and living), which is the most important factor of higher moisture content: moisture is retained more than it is increased.–A.B. & M.C.

[142] This is incorrect: the dark color is carbon, and is created by organisms. Using Tullian husbandry, the soil will darken many feet below the surface, and, over time, require less and less tillage, becoming something akin to what is sold at nurseries as "potting soil."

[143] In Mr. Jethro Tull's text, the Latin appeared: "hic sterilem exiguus ne deserat humor avenam." Justin Walker suggests the Latin was not transcribed accurately. His correct transcription appears here: "hic sterilem exigu(o)us ne deserat humor (h)arenam." Mr. Walker explains: "it is not usual for the adjective 'exiguus' to have an 'o.' I am ambivalent to the inclusion of the 'h.'" –A.B.

Tillage prevents flooding and reduces compaction due to rain

Although hard ground, when thoroughly soaked with rain, will continue wet longer than fine tilled land adjoining to it, this water serves rather to harm than nourish the plants standing therein and keep out the benefits of the atmosphere, leaving the ground harder still when it dries and, at last becoming dry it can admit no more moisture except from a long continued deluge of rain (which seldom falls until winter and is not the season for vegetation).

Fine hoed ground never becomes perfectly dry; this is evidenced by the plants, which flourish and grow fat in fine hoed ground while those in hard ground are starved (except those plants which stand near enough to the hoed earth for their roots to borrow moisture and nourishment from it).

Experiment showing hoeing will feed crops mid-season

When wheat is drilled late in very poor land by the common method, the young plants look all very yellow by the spring. Let your hoe-plow, make a crooked line (like a parenthesis[144]) on one side of a straight row of this poor wheat in the spring, turn a furrow from it, and in a short time you will see all those young plants that are contiguous to this furrow change their yellow color to a deep green...even while those plants of the same row which stand farthest from this crooked furrow do not change their color until long afterwards. You will notice that all the plants change or retain their color sooner or later gradually as they may stand nearer or father from the crooked line and that other rows, which have no furrow in them, continue yellow after all this row has become green and flourishing.

But this experiment is best to be made in poor sandy ground, when the mould is friable, else perhaps the different color may not appear until the furrow is turned back to the row, having lain some time to be somewhat pulverized by the weather.

This experiment I often made on wheat drilled on the level, before I drilled any on ridges.

Well tilled aisles feed beds of plants

I have never seen a plant contiguous to a well-hoed aisle that grew poorly...unless it was overpowered by a too-great multitude of other plants (or if the plant required more or less heat or moisture than the soil or climate afforded).

Hoeing improves arid soil and counteracts drought

Though ignorant and incurious people fancy that hoeing lets in the drought (and therefore are afraid to hoe their plants at such times when, unless they water them, they are spoiled for want of it), I have been informed by some persons that they have often made similar observations to mine: that in the driest of weather, good hoeing procures moisture to the roots. But note: to hoe with advantage against dry weather, the ground must have been well tilled or hoed before so that the hoe may go deep, or else the dews that fall in the night will be exhaled back in the heat of day.

[144] Tull's word was "indenture." –A.B. & M.C.

Hoeing increases the quantity and quality of plant roots

There is yet one more benefit hoeing gives to plants that by no art can possibly be given to animals (for all that can be done to feed an animal has already been said here of hoeing, namely, to give the plant or animal sufficient food and drink at the times the plant or animal has occasion for them).

If you give an animal more food than it can eat (unless you can give the animal more mouths – which is impossible), the kindness done for the animal serves no purpose. But when a plant is hoed and thereby given more food, the plant will send out innumerable new fibers and roots as the Mint F did[145], to increase the number of its mouths in some proportion to the increase of food given to it. The cutting of the roots stimulates the growth of new roots: these new roots are small and ideally adapted for eating. Hoeing, by the new pasture it raises, furnishes both food and mouths to plants. It is for want of hoeing that so few are brought to their full growth and perfection.

Hoeing increases the size of plants

Land was drilled with ryegrass and barley in rows at five inches distance from each other. It produced a pretty good crop of ryegrass the second year (as usual). There was adjoining to it a ground of turnips that were in rows, with wide aisles horse hoed. These turnips stood for seed and amongst them was room enough for one rye plant which, being hoed as the turnips were, had (in every one's opinion that saw it) acquired a bulk at least equal to a thousand rye plants in either ground. This one rye plant had no other advantage above the other rye except its singleness and the deep hoeing.

Many other species of plants have I seen thus increased beyond common size by deep hoeing, but none so much as a chickweed and a mustard-seed plant (whose collateral branches were much bigger than a whole plant of that sort: the top of the mustard was taller than I could reach and seemed more like a tree than an herb).

Harrowing is bad husbandry; criticism of Roman techniques

In what manner the serration of the ancients was performed in their corn is not very clear, but this seems to be something like this: some time after the plants had sprouted, they harrowed the ground and pulled out the weeds by hand. This process appears in Columella, when he directs the planting of alfalfa followed by a sort of harrowing or raking among the young plants so that the weeds might come out easier. "The sown seeds should be earthed over immediately with wooden mattocks. After this, the field should be hoed with wooden mattocks and weeded again and again,

[145] For the reader's convenience, we have inserted the description of Mint F from the Chapter on Roots here: "I have observed with another mint (marked "F") that when mint has stood in a glass of water until it seemed to have finished its growth, the roots are a foot long and of an earthy color. When I put some fine soil into the water, it sunk to the bottom and soon there came from the upper joint a new set of white roots. These new white roots took their course on the outside of the heap of old roots downwards until they reached the earth at the bottom. Then they came to be of the same earthy color as the old ones."

so that a plant of another kind does not destroy the weak clover (or, some other such medicinal plant)."[146] They harrowed and hoed with Rastris[147]: their harrowing and hoeing were performed with the same instrument and the difference between harrowing and hoeing was only in the time they were undertaken: their harrowing was conducted at seed-time to cover the seed or level the ground, their hoeing was to move the ground after the plants were sprouted.

For the better understanding of these two sorts of serration, we must consider that the ancients sowed their corn under the furrow (that is, when they harrowed the ground to break the clods and make it level, they sowed the seed and then plowed it in). This process left the ground very uneven, and the corn came up (as it still can be seen when the process is repeated) mostly in the lowest places betwixt the furrows. Virgil remarks upon the time "when the crops are equal to the furrows"[148].

They first harrowed length-ways of the furrows which, being somewhat hardened, let a little soil be thrown down onto the young corn. Then they harrowed across the furrows, which threw down much soil onto the corn.

How this practice continued to make the corn fruitful is another question: I am in no doubt to say that it was not from covering any part of it (for I see that such a practice has a contrary effect), but the fertility rather was gained from moving so much ground as to give a new pasture to the roots of the corn. Moving soil onto the roots without hoeing is an injury to the plant.

Virgil also says, "the bean and other legumes shall be hoed correctly when they protrude from the soil by four fingers, with the lupin excepted (the hoeing of which is harmful to the seed because it has only one root: if it is cut or wounded by a blade, the entire shoot perishes)."[149]

If they hoed it only between the rows, there had been no danger of killing the lupine (which is a plant quite suited for hoeing, when hoeing is undertaken properly). What Virgil says (of lupines having no need of serration because lupine is able to kill weeds) shows the ancients were ignorant of the chief use of hoeing: to raise new nourishment by dividing the soil and making new internal surfaces in the soil for the pasture of plants.[150]

Such serration scratched and broke so small a part of the soil's surface, and scratched and damaged the corn and weeds without distinction (without favoring one or the other), that it can be disputed whether the serration did any good at all[151]. In facilitating the runcation (hand weeding),

[146] "Ligneis Rastris statim jacta semina obruantur. Post sationem Ligneis Rastris sarriandus et identidem rncandus est Ager, ne alterius generic herba invalidam Medicam perimat," translation by Justin Walker.

[147] A type of pronged hoe with usually one to four teeth, but sometimes more. –A.B.

[148] "Cum sulcos equant sata," translation by Justin Walker.

[149] "Faba et caetera Legumina cum quatuor Digitis a terra extiterint recte sarrientur, exceepto tamen Lupino, cujus Semini contraria est Sarritio; quoniam unam Radicem habet, que sive Ferro succisa seu vulnerata est, totus Frutex emoritur," translation by Justin Walker, who also corrects the given spelling of "quatuor" to "quattuor."

[150] The ancients are not the only ones who use this argument against tillage. Advocates of no-till systems encourage the use of allopathic plants for weed control, and (wrongly) say that there is little need to till because the plants can take care of themselves. –A.B. & M.C.

[151] It is important to learn whether the return of any pesticide, herbicide or fertilizer warrants its use. If the treatment costs more than it returns – through saved plants, increased production, etc. – than it should not be used. The long-term effects of many chemical applications render them

the benefit of serration was greater than the injury it did to bruising and tearing the corn, but many of the ancients chose to content themselves with the use of runcation only and totally omit all serration of their corn.

Hoeing is very different from serration, and is in every way beneficial and not injurious to the corn (even if it is destructive to the weeds). Therefore some modern authors show a profound ignorance in mistaking their translation of "sarrito" for "hoeing." By doing so, they give an idea very different from the true one. The ancients truly did hoe their vineyards—but not their corn. They did not plant their corn in rows, without doing which they could not give it the vineyard hoeing. Their sarculation (the use of a type of very narrow hoe) was used among only some varieties of corn (as it is still in use for broadcasted flax: this operation is too tedious and too expensive to be applied to great quantities of broadcasted corn). They did not take the pains to plant their crops in rows to ease hoeing between them with their bidens (the instrument they hoed their vineyards—the bidens enters as deep as the plow and is much better than the English hoe which, indeed, seems designed better to scrape chimneys than to till the ground).

Praise of the vineyard hoeing methods, applications to grain and orchards

The highest and lowest vineyards are hoed by the plow. First the high vineyards, where the vines grow (almost like ivy) upon great trees, such as elms, maples, cherry trees, etc. These high vineyards are kept constantly in tillage and produce good crops of corn, beside what the vines and trees yield. The vines owe this productivity to the hoeing tillage because neither in the meadow or pasture can vines be made to prosper

The vines of low vineyards[152], hoed by the plow, have their heads just above the ground, standing in a most regular order and are constantly plowed in the proper season: these have no other assistance but hoeing: because their heads and roots are so near together, in those hot countries, dung would spoil the taste of the wine they produce.

All vineyards must be hoed in one way or another: vines that cannot be hoed by the plow are hoed by the bidens. If vineyards are not hoed, they will produce nothing of value. Yet cornfields without hoeing do produce something—though nothing in comparison to what they would do with hoeing.

From these I took my vineyard scheme, observing that middling land could produce an annual crop of grapes and wood without dung; and though there is annually carried off from an acre of vineyard as much in substance as is carried off in the crop of an acre of corn produced on land of equal goodness, the vineyard-soil is never impoverished unless the hoeing culture is denied it while a few annual crops of wheat, without dung in the common management, will impoverish and emaciate the soil.

I cannot find either in theory or practice any other good reason for this difference except that the vineyard-soil is more pulverized by hoeing and not exhausted by too many plants as the corn fields in the common management are. Indeed, corn field are typically exhausted by above ten times the number of plants that should stand on an acre.

unprofitable, and just as manure is less profitable than no manure, the farmer will eventually rely solely on tillage.

[152] Most modern vineyards are of this low kind: grapes are trellised on wires and posts that stand not usually more than 4 feet tall. –A.B. & M.C.

Mr. Evelyn says that when the soil that fruit trees are planted in is constantly kept in tillage, the trees grow up to be an orchard in half the time they would do if the soil were not tilled.

In some places in Berkshire they hand hoe most sorts of corn with great success. But I say this knowing that so many hands are required for this that the improved yield has never adequately answered the increased expense. This is possibly one reason why the ancients were not able to introduce the practice into their cornfields: not for ignorance of the effect of tillage, but for the expense.

The Horse Hoeing Husbandry

I shall now give some general directions which, by experience, I have found necessary to be known in order to practice this hoeing-husbandry.

1. Concerning the Depth to Plant At
2. The Quantity of Seed to Plant
3. The Distance of Rows

1. Concerning the depth to plant at: undertake trials by planting at various depths and observing which are too shallow, and which are too deep depending on the kind of soil and the kind of seed

It is necessary to know how deep we may plant our seed without danger of burying it at a depth greater than from which it is able to come up.

Different sorts of seeds come up from different depths. Some come from six inches or more, some not more than half an inch. The way to know for certain the depth any sort of seed will come up at is to make an experiment in this manner: make twenty rows of twelve holes, the first hole a half inch deep, the next hole an inch deep, and every next hole a half inch deeper than the one previous to it until the last hole is ten inches deep. An easy way to do this is to use wooden dowels that have been sharpened at one end to ease their penetration into the soil, cut to the appropriate depth. Plant into each hole the seed in question, and observe which planting depth results in the greatest number of sprouts. Observations over the growing season will demonstrate which planting depth is the best for your field: which depth allows good sprouting, good tolerance of drought, good tolerance of flood, of pests, of heat, of cold, etc.

When the depth at which the seed is sure to come up is known, we may easily discover whether the seed is good or not by observing how many seeds will fail. In some sorts of seed, the goodness cannot be known by the eye and there has been a great loss by bad seed. Loss by bad seed not germinating and loss by burying good seed too deep or too shallow may be prevented by taking this little trouble.

The nature of the land, the manner how it is laid (either flat or in ridges) and the season of the planting (with the experience of the planter acquired by such trials) will affect the most proper depths for different sorts of seeds.

2. The quantity of seed to plant I: much less is required per acre if properly spaced; properly spaced plants produce more per acre – one properly spaced plant will produce more than 50 improperly spaced plants

The proper quantity of seed to be drilled on an acre is much less than must be sown in the common way (by broadcasting), not because hoeing will not maintain as many plants as the common way might: on the contrary, experience shows that hoeing will always maintain more. The different quantity of seed to be drilled is for other reasons: it is impossible to sow seed as evenly by hand as the seed drill will do. The hand cannot broadcast it as exactly as the seed drill (especially in windy weather) and the unevenness of the ground will alter the situation of the seed (the greatest part rebounding into holes and the lowest places). The subsequent harrowing used in the common method will then draw the seed into the lowest parts of the field so that the low places might have as much as ten times the seed as is necessary, and the high places none at all.

This inequality of seed distribution reduces the average productivity of the seed. Fifty seeds in the space that one should be will not produce as much as one seed properly spaced will produce. Where seeds are too thick they are undernourished.

Also, when seeds are broadcasted they cannot receive the hoe to pulverize the soil and their roots will not spread very far for want of hoeing to open the soil, the plant will not eat as much and will not be so productive.

2. The quantity of seed to plant II: less seed is required if all are planted at the correct depth

And, when not drilled, some seed is buried so deep they are never able to come up again (as Columella cautions, "that they be buried without any hope of springing up again"[153]).

In the common method, some seed lie naked above the ground, which, with the first rain, feeds only the birds and vermin.

Farmers know not the depth that is enough to bury their seed, neither do they alter the quantity they sow on a rough or on a fine acre (though the same amount, which is too little for one, is too much for the other). To farmers using the common method, planting is chance-work, and they put their whole trust in good ground and much dung to cover their errors.

Yet farming need not be a gamble with a seed drill.

The greatest quantity of seed I ever heard of to be usually sown is in Wiltshire where, I am informed by the owners themselves, that on some sorts of land, they sow eight bushels of barley to an acre so that it will produce 32 bushels to an acre. This is on land that is plowed only once and then double dunged: the seeds are harrowed into the stale and hard ground and so only two bushels of every eight that is sown grows. In a dry summer, an acre of these two bushels produces four bushels at harvest. Four grains grown for every one sown is a very poor increase...even if it may be a good crop.

But in drilling, we seed less seeds all at the same depth. None are deeper, none are shallower than the rest. There is no danger of accidents burying or uncovering the seed and therefore there is no need to make allowances for such accidents that arise when the seed is too deep or too shallow (such as grubs, flies, worms, frost, etc.).

2. The quantity of seed to plant III: less seed is needed if seed is good

A person who is inexperienced in this method must prove the goodness of their seed (how many viable seeds per bushel) as well as and the depth at which it ought to be planted

[153] "Ut absque ulla resurrectionis spe sepeliantur," translation by Justin Walker.

2. The quantity of seed to plant IV: do not estimate by volume for all seeds: more seeds will be in a bushel of small seeds than in a bushel of large seeds; calculate the number of good seeds per bushel, how closely they will be planted, how many rows will be in a bed and determine how many seeds will be required per acre

The farmer ought then calculate what number of seeds a bushel (or other measure or weight) contains: one bushel (or other measure or weight) of small seed may contain double the number of seeds in a bushel (or other measure or weight) of large seed of the same species. This calculation is made by weighing an ounce and counting the number of seeds therein. Then, weigh a bushel of the seed and multiply the number of seeds in the ounce by the number of ounces in the bushel's weight. The product will show the number of seeds in a bushel near enough.

Once the number of seeds per bushel is known, the amount of land it will plant should be determined. Consider how closely you intend on planting the seed, and how many rows you will have per bed (the more rows per bed, the more seeds you will require), and how many seeds it takes to plant 100 square feet. Multiply that number by 435.6 (because there are 43,560 square feet in an acre).

But what is a bed, and how do you decide how many rows to have on a bed?

3. The distance of rows I: the definition of a bed

The area that plants are seeded is called a bed. The narrow spaces between rows within a planting bed are called partitions. The wide space between any two of the beds are called aisles.

3. The distance of rows II: choosing how many rows per bed

It is important to consider how you will plant the rows in the bed: whether single, double, treble or quadruple. The more rows, the more seed will be required per acre.

3. The distance of rows III: arguments for wide aisles and few rows

Though there is much proof arguing for wide aisles, the world is prejudiced against wide spaces between rows and beds from false notions. Unless these common (and I wish I could say, vulgar) objections are first answered, nobody will venture experiments to gain the experience necessary to know lies from truth.[154]

[154] We would refer such objectors to preceding chapters, though the theme continues to be developed throughout the work. –A.B. & M.C.

3. The distance of rows IV: polycultural methods

I formally was at pains and some expense in improving my drills for planting rows at very near distances and had brought them to such perfection that one horse could draw a drill with eleven shares, making the rows at three and one-half inches distance from one another and, at the same time, sow in them three very different sorts of seeds (without them mixing) at different depths: the barley rows were seven inches apart and lay four inches deep, in the same channels at one inch deep lay broad clover, between every two of these rows was a row of sanfoin at one-half inch deep and hop clover at one inch deep.

I had a good crop of barley the first year; the next year, two crops of broad-clover (where they had been sown) and, where the hop clover had been sown, a mixed crop of that and sanfoin.

Every year after that, I had a crop of sanfoin, but I am since, by experience, so fully convinced against mixing crops and more especially against narrow spaces that I have demolished these instruments (which had been perfected) as a vain curiosity, the use of them being contrary to the true principles and practice of horse hoeing.[155]

Wide aisles are shocking, but are necessary for greater production; longer-lived, bigger plants are better served by wide aisles, but small, short-lived plants also significantly benefit

Although I am satisfied that everyone who shall see as much of it as I have will be of my mind in this matter, I am aware that what I am going to advance will seem shocking to them before they have made trials.

Wide aisles are necessary for horse hoeing. Because of the extent of the roots, larger plants have greater benefit from wider aisles than small plants, smaller plants have greater benefit from smaller aisles than large plants.

General rule: narrower beds for barley than for wheat because it grows in 1/3 time wheat does and is smaller than wheat.

I lay it down as a rule to myself that I make the aisles narrower for annual crops of barley[156] than for wheat because it grows in about 1/3 of the time wheat does, is smaller than wheat and requires less room for hoeing, and does not shut out the hoe-plow so soon.[157]

[155] We have repeated his trials and were not so dissatisfied – so long as the polyculture was undertaken with wide rows and the overall density was reduced. This method, while impracticable for hay is ideal for vegetables and fruits when a farmer needs to conserve land and still produce crops constantly through the year. –A.B. & M.C.

[156] The farmer that drills barley must resolve to reap it and bind it up in sheaves, for if he mows it or does not bind it, a great part will be lost among the earth in the aisles.

[157] Yet I think that six-foot beds for barley, planted in quadruple rows (at 18 inch aisles) is quite profitable – especially on thin soil.

Inferiority of hand hoeing – it moves less soil

In hand hoeing there is always less seed, fewer plants, and a greater crop than in the common sowing. Yet with hand hoeing, the rows must be much nearer together than in the horse hoeing because the hand hoe moves many times less earth than the horse: the roots of plants are sent out less far in hand hoeing.

If the aisles where the hand hoe only scratches a little of the upper surface of them are too wide, the soil would be so hard and stale underneath the scratching that the roots of perennial plants would take a long, difficult time in running through them and the roots of many annual plants would never be able to do it at all.

Horse hoe inferior only to spade

The difference between hand hoeing and deep hoeing is pronounced. I knew a certain poor man whose cabbages were larger than everybody else's—though all his neighbors' fields were richer and better dunged. His neighbors were amazed at the size of his cabbages until the secret at length came out: while his neighbors hoed their cabbages with a hand hoe, he used a spade. And nothing can nearly equal the use of the horse hoe than the spade.

Objections to planting in rows and aisles I: aisles are wasted spaces. Yet, though nothing grows on their surface, there is much activity underneath and better activity underneath than would the plow not be regularly tilling there; this greater activity increases the production of the beds

The objections most likely to prejudice people's minds and prevent their making trials of this husbandry are these:

1) People might be apt to think that these wide, naked spaces between beds that are not covered by crops will reduce yield enough that it is impossible to have a good crop.

For answer, we must consider that though corn standing irregular may seem to cover the ground better than when it stands regular in rows, this appearance is an optical illusion[158]. For the eye to make a comparison between a broadcasted crop and a horse hoed crop, it ought to look *across* the rows because, if well managed, it will appear more beautiful at harvest than a broadcasted crop.

Stalks are never so thick on any part of the ground as where many come out of one plant (as when they stand in a row), and a hoed plant of corn will have twenty or thirty stalks in the same quantity of ground where an unhoed plant, being equally single, will have only two or three stalks. I have counted as many as fifty large ears on one single hoed plant of barley! Hoed rows contain, in reality, a greater crop than the broadcasted, and it is only the different placing of the plants that makes the one that is lesser seem greater, and the one that is greater seem lesser.[159]

[158] Mr. Jethro Tull's words were "Deceptio visus." —A.B.

[159] Today, though planting in rows is accepted, a similar objection is that wide rows separated by aisles is an inefficient use of space. This objection is has the same answer as Tull just gave: planting in narrow rows with no aisles is little better than random broadcasting of seed with no aisles. The only improvement to narrow rows and no aisles is that the seed is planted more regularly than by broadcasting! –A.B. & M.C.

Objections to planting in rows and aisles II: planting in wide rows reduces yield. Yet, if planted to closely, each plant produces less, and the total field's production is less

2) The next objection is, with the wide spaces between rows not being planted, much of the potential yield of that ground is lost, that the crop must be less when planted in wide rows than if it were planted all over.

I answer that it might be so if the plants did not eat more in wide rows, even if not horse hoed. If it is well hoed, the roots can run through the aisles and aisles and, having more nourishment, make a greater crop. But, when too great a number of plants are planted together, even if the aisles are well hoed, the plants are starved; and, even if there is sufficient space between each plant, if not planted in rows, their irregular standing prevents their being relieved with fresh supplies from the hoe: not every plant equally can access the aisles where there is food for them! The old method exhausts the soil to no purpose and produces a lesser crop, leaving less food behind for the next crop.

Some will object that so small a part of the ground is planted when planting is done in rows that the ground cannot contain plants or stalks sufficient for a full crop.

This argument some authors endeavor to support by observing the perpendicular growth of vegetables and the room they require to stand on. Both of these arguments I have answered previously and need not say much of them here, but I may add that if plants could be brought to as great perfection and stand as thick all over the land as they do in the hoed rows, there might be produced at once many of the greatest crops of corn that ever grew.

Wider aisles are better; in experiments, dung without hoeing did not equal hoeing without dung, and among 12 differences of wider and narrower aisles and beds (each wider trial being proportionally more dunged) and a control trial of broadcasting, wider did better and that which was broadcasted did worst of all: broadcasted yielded only 20% of that which was widest and most hoed

In a large ground of wheat it was proved that the widest hoed aisles brought the greatest crop of all: dung without hoeing did not equal hoeing without dung. And, what was most remarkable, among twelve differences of wider and narrower spaces (each of the twelve being more or less hoed, dunged and undunged) and a broadcasted control trial, that which was broadcasted was considerably the worst of all—even though through the winter and the beginning of spring they made the most promising appearance. At harvest, the broadcasted yielded only 20% of the wheat that was planted widest and most hoed!

Some of the most hoed crops yielded eighteen ounces of clean wheat in three feet of a double row (the aisles being thirty-six inches wide, and the two rows six inches apart). At the same harvest, three feet of a double row of barley planted similarly produced eight hundred and eighty ears, but the grains happened to be eaten by poultry before it was ripe (so that their produce of grains could not be known). Lammas wheat[160] planted in the same way produced four hundred ears in three feet.

[160] A variety's name. –A.B. & M.C.

Plants produce in proportion to the nourishment they have within the ground, not the space they have to stand upon it

Plants thrive and produce in proportion to the nourishment they have within the ground...not to the space they have to stand upon it.[161] One very narrow row may contain more plants than a wide aisle can nourish to their full perfection.

A quick hedge, standing between two arable grounds, one foot broad at bottom and eighteen foot in length, will, at fourteen years growth, produce more of the same sort of wood than if planted in an eighteen foot square and allowed to grow in the same time (the soil of both being of equal goodness). After fourteen years, the product of the coppice is much less than that of the hedge whose pasture has not been overstocked to such a degree as the coppice pasture has been. Because the hedge has not been stressed for lack of food, the hedge brings its crop of wood to greater perfection than the coppice. The hedge has the further benefit of hoeing whenever the arable land on either side of it is tilled; the coppice like a broadcasted crop, wants that benefit.

It is the same case with our hoed rows.

Observing only those parts of a plant above the ground leads to false beliefs: discussion of the theories of Laurence and Bradley

It is no great wonder that astronomers take notice of those parts of plants alone which exist within that element they are accustomed to make their stellar[162] observations...or treat of plants only as they regard their zenith, not inquiring what is done by the roots within the earth's dark recesses, not inquiring how much of a plant's dimension is necessary to employ the roots in their office. Even so, I should have thought Mr. Laurence a better scientist than to be so much imposed upon by that quibbling fallacy of Mr. Bradley's (about the perpendicular growth of plants) as to call it a demonstration: "And as the Hills, tho' they measure neat Twice as much as the plain Ground they stand upon; yet the Produce of the one can be no more than the Produce of the other," see Mr. Laurence's *New System*, page 63.

It is very likely that the Reverend gentleman may have had opportunities (unless he preaches no better than he plows) of seeing all his parishioners stand perpendicularly in his church (as in a row) and, his tithe putting him in mind that many acres of space (more than his church's area, to be sure) are necessary for their nourishment—without which nourishment, hunger would soon bring

[161] Today, a proponent of this idea is Mel Bartholomew, the author of *Square Foot Gardening* who designed an intensive method based upon how closely he could plant things together: so long as they have enough nourishment and enough space to grow into mature plants, Bartholomew is satisfied to even plant them on top of each other, allowing a spinach to grow where the squash has not yet expanded to and using fertilizers, pesticides and herbicides to compensate for what deficiencies there may be in the soil and in his method. —A.B. & M.C.

[162] Tull is referring to the stellar (in this sentence, a play on words that implies both a sarcastic sense of "good" and the literal reference to that which deals with stars) observations of Newton and Laurence, who had recently published writings on agriculture. –A.B. & M.C.

them from their perpendicular posture to a horizontal one, forcing him to perform his last office for them all at once.

It is just so with plants, though these gentlemen by their arguments about them seem to think otherwise. Why else would they attempt to calculate the quantity of the earth's surface necessary for them by the manner of their growth?

Plants that grow parallel to the ground are more difficult to hoe than plants that grow perpendicular; parallel plants need wider aisles, training or trellises

It is nothing to the purpose whether a plant's growth is perpendicular or not, but it is true that perpendicular plants have the most benefit by hoeing because by that posture they admit the hoe to come the oftener among them.

In wide aisles there is another advantage: there is room for many[163] hoeings. Because plants may grow into the aisles, it is not possible to hoe mature plants in narrow aisles.[164] While it is advisable to not damage tubers, stems and other essential parts of the plant, in narrow aisles it is impossible to avoid damaging the plants that grow closest to the aisle.

[163] If it should be asked how many, use Columella's rule in hoeing the vines: "Moreover, to confess the truth, no limit should be set to the number of times that the ground is to be turned by the hoes, since it is agreed that the more frequent it is, the more beneficial is the digging. But, since consideration for expenses demands some limit, it has seemed sufficient to most people to dig newly planted vineyards every thirtieth day from the Calands of March up to October, and to root out all weeds and especially the grasses; for these, unless pulled out by hand and thrown on the surface, return to life when any least part of them is covered with earth, and so scald the vine plants as to make them scaly and shriveled." ("Numerus autem vertendi soli bidentibus, ut verum fatear, difiniendus non est, cum quanto crebrior sit, plus prodesse fossionem conveniat. Sed quoniam impensarum ratio modum postulat, satis plerisque visum est, ex Calendis Martiis usque in Octobres tricesimo quoque die novella vineta confordere, omnesque herbas et praecipue gramina exstirpare, quae nisi manu eliguntur et in summum reiciuntur, quantulacumque parte adobruta sunt, reviviscunt, et vitium semina ita perurunt, ut scabra atqueretorrida efficiant." –Col. Lib. 4, Cap. 5. Translation from Harrison Boyd Ash's book, *Lucius Junius moderatus Columella On Agriculture*, published in 1940 by Harvard University Press in Cambridge, Massachusetts.). The "scalding" referred to by Columella might be dehydration. We till our fields every month (or oftener)—even in the winter (but only in the aisles until spring, when we will till the beds as well). —A.B. & M.C.

[164] Plants, such as the squash, can be problematic to hoe as their vines wander into the aisles. However, training or trellising of individual plants or the use of varieties that are more perpendicular in stature relieves this difficulty. –A.B. & M.C.

Hoeing late in the year is also beneficial to plants, not despite but because it damages roots, allowing them, like the Mint F of the first Chapter, to send out a greater number of roots from their wounds into fertile soil

Hoeing late into the year is beneficial to plants, not despite but because it damages roots. As seen in the experiment of Mint F of the first chapter, plants send out a great number of roots from their wounds into fertile soil.

With wide aisles, those roots are broken off only where they are small and, though the plants are capable of running out roots to more than the length of their height, it is not necessary that they do so if they can have sufficient food nearer to their bodies...and soil is never so near to the bodies of plants as it is when the row stands on a narrow bed surrounded by wide, well hoed aisles.

New roots late in the season have more mouths per area than older roots, and more food to eat

These new young multiplied roots have more lacteal mouths per area than the older ones, which makes it no wonder that plants should thrive better by having some of their roots broken off by the hoe: for as roots do not enter every pore of the earth but miss a great part of the pasture (which is left unexhausted), so when new roots strike out from the broken parts of the old, they meet with that unexhausted pasture that their predecessors missed (besides the reinvigorated pasture which the hoe raises for them).

Corn that is broadcasted needs more seed and yields less per seed

Corn that is broadcasted requires about three times as much seed as corn that is drilled. Being three times as numerous, the plants exhaust the soil faster and before the plants grow large, the pores of the Earth are shut against them and against the benefit of the atmosphere. But the drilled corn gives the hoe constant admission, and the hoe admits the benefit of the atmosphere and opens up the pores for the plants! The hoe produces more food than the plants can eat, and the drilled corn leaves food for a succeeding crop while the broadcasted corn robs its successors.

While it is impossible to bring these calculations of how much food is exhausted or left to mathematical rules, it is still certain in practice: a broadcasted crop succeeding a large unmanured hoed crop is much better than a broadcasted crop which succeeds a small manured broadcasted crop. And I have the experience of a poor, worn out heath-ground that, even after having produced four successive good hoed crops of potatoes (the last still best), has become good ground.[163]

[163] Tull conducted a trial to demonstrate that when space is left between beds wide enough for repetitions of hoeing, the hoe can raise more nourishment to the plants than a good coat of dung with common tillage: "In a very poor Field were planted *Potatoes*, and in the very worst part of it, several lands had them in Squares a Yard asunder; these were plowed Four ways at different times; some other Lands adjoining to them, of the very same Ground, were very well Dung'd and Till'd; but the *Potatoes* came out irregularly, in some places thicker, and in others thinner; these were not Ho'd, and yet at first coming up, looked blacker and stronger than those in Squares not Dung'd, neither that Year, or ever, that I know of; yet these Lands brought a good Crop of the largest *Potatoes*, and

Crop rotation is entirely unnecessary: hoeing supplies all the nutrients required for crop health; this sort of hoeing has the same effect as a summer fallow; those plants that have reputations for improving the soil require tillage, and tillage is the true source of the fertility

The more successive crops that are planted in wide aisles and hoed often, the better the ground maintains them: the last crop is the best, without dung and without changing the sort of plant. This is so visible in parts of the same field where some part has a first, some other part a second, the rest a third crop all growing at the same time that it proves that the Earth is brought by hoeing to dispense or distribute her wealth to plants in proportion to the increase of her inner surfaces (which is the pasture of plants) and the atmosphere, by the riches in rain and dews, does annually reimburse in proportion to the same surfaces—with an overplus of interest!

But if the surfaces are not increased to a competent degree by frequent hoeing, this advantage is lost and, without repeated tillage, every year's crop grows worse. This may be evidenced by trials which will admit no dispute. Hoeing, without dung or fallow, can make such plants as stand in wide aisles more vigorous in the same ground than both common dunging and fallowing can do without hoeing.

This sort of hoeing has, in truth, every year the effect of a summer-fallow—except, unlike a summer fallow[165], it produces yearly a good crop.

Some will argue that a particular plant fertilizes the soil, others impoverish it. However, there is, I think, a commonality among all those plants reckoned to be among the enrichers: those that are among the enrichers require frequent, deep hoeing, and the other good practices of the horse hoeing husbandry.

While there are some plants (by the nature of their constitution) are great devourers of food, there is yet no reason to not believe that if the hungriest plant of them all is well hoed, it would gain the reputation of an enricher or improver of the soil.

Maximum Width Between Rows

The wider the aisles are, the more the soil may be hoed. Because the area between rows may not be hoed, it is wise to not allow the row width to exceed that distance which may be easily hoed.

There are many ways of hoeing with the hoe plow, but there is not room to turn two deep, clean furrows in an aisle that is narrower than fifty-six inches[167]. If the aisle is much shorter than

very few small ones amongst them; but in the dung'd Lands, for want of Hoeing, the *Potatoes* were not worth the taking up; which proves, that in those plants that are planted so as to leave Spaces wide enough for Repetitions of Hoeing, that Instrument can raise more Nourishment to them, than a good Coat of Dung with common Tillage." —A.B. & M.C.

[165] This active fallow rejuvenates the soil quicker than agriculture depletes it and, because it not only sustains production but improves it as well, can even reclaim damaged or depleted lands. Profit can be earned by obtaining damaged or depleted lands cheaply and bringing them into tilth. – A.B. & M.C.

this, one of these furrows (at least) will reach and fall upon the next row—which will be very injurious to the plants.

Slippery clay hills are the only kind of soil not good for hoeing husbandries

Much of hoeing in general may suffice different sorts of plants requiring different management. But it may not be amiss to add that all sorts of land are not equally proper for hoeing: dry, friable soil is best. Intractable wet clays and such hills that are too steep for cattle to draw a plow up and down them are the most improper for by hoeing. Even if the furrow is drawn across the hill, the furrow turned towards the declivity cannot be thrown up near enough to the row above it, and the furrow that is turned downwards will bury the row below it.[168]

And yet, as improper as mountains and slippery clays are for hoeing, they are not so improper as those Virgillian principles that have bound the owners of land to such unreasonable, unscientific and illogical principles as crop rotation and fallow.

Jethro Tull's Supplement

Hoeing turnips allows for continuous crops

Turnips that stand for seed are such devours and feed so long on the soil that, when not deep hoed and only hand-hoed, such a shallow operation does not supply the usual thickness of those plants with pasture sufficient to raise their stems to half their natural bulk and they leave so little of that pasture behind them that the soil is observed to be extremely impoverished for a year or two and sometimes three years after them.

My horse-hoed turnip-seed never failed to yield to a good crop of barley after being sown on the level the following spring, even when no dung had been used on the land where the turnip-seed grew for many years.

And also my barley-crops thus sown after two successive crops of turnip-seed without a fallow between them are as good as those sown after a single crop of it. For I have several times made these turnip-seed crops annual, that is, to have two crops of it in two years (which would in the old way require three years, because this crop stands about a year on the ground and is not ripe until midsummer, which is too late to get that land into a tilth proper to plant another seed-crop on it the same summer. And the soil in the old way cannot bear such another crop immediately after being so much exhausted and unplowed for a whole year, unless it is extraordinarily rich or much dunged).

Two crops of turnip-seed immediately succeeding one another is what I never knew or heard of except my own that were horse-hoed. And of these the second crop was as good as the first: their stalks grew much higher than they usually do in the common way and though the number of plants

[167] Modern technology has improved this width. Spading machines and rototillers allow tillage in an area as small as 30 inches while eliminating the need to make two passes on one aisle. —A.B. & M.C.

[168] However, hand shoveling or the construction of terraces can bring even the mountains under hoeing husbandries. —A.B. & M.C.

was much less, their produce was so valuable, that the Vicar's agent[169] declared he collected for tithe twenty shillings per acre more than another whole field which he tithed in kind. The expense of these crops was answered by the fuel of the threshed stalks. It must be noted, that the extraordinary value of these crops arose not from a greater quantity of seed than some common crops, but from their quality, experience having brought this seed into great esteem on account of its being perfectly clean, and produced by large turnips of a good sort, and of a proper shape; for those that are not well cultivated are very apt to degenerate, and then their seed will produce turnips of a small size, and of a long rapy ill shape.

Good Conditions

Plowing in sandy or mellow ground makes a pulverization that is enjoyed by those plants that are the nearest to it while also delivering them from weeds, which, though they may be very few, leads to a vast difference between their robbing the wheat of its pasture in the row and the wheat's enjoying both that and the whole pasture of the row also.

I never remember to have seen a plant poor that was contiguous to a well-hoed internal, unless overpowered by a too great multitude of other plants; and the same exception must be made, if it were a plant that required more or less heat or moisture than the soil or climate afforded.

But to hoe with advantage against dry weather, the ground must have been well tilled or hoed before so that the hoe may go deep, or else the dews that fall in the night will be exhaled back in the heat of the day.

Serration

Hoeing is an action very different from serration and is every way beneficial and no way injurious to corn, though it is destructive to weeds; therefore some modern authors show a profound ignorance in translating *sarritio* for hoeing. They give an idea very different from the true one. The ancients only truly hoed their vineyards, and not their corn, neither did they plant their corn in rows, without which they could not give it the vineyard-hoeing. Their sarculation was used only among small quantities of corn, and is yet in use for flax, for I have seen the sarculum, which is a sort of very narrow hoe, used amongst the plants of flax standing irregularly, but this operation is too tedious and too chargeable to be applied to great quantities of irregular corn.

If they hoed their crops sown at random, one would think they should have made mad work of it; since they were not at the pains to plant in rows and hoe between them with their bidens, the instrument with which they tilled many of their vineyards. The biden enters as deep as the plough and is much better than the English hoe, which indeed seems, at the first invention of it, to be designed rather to scrape chimneys than to till the ground.

[169] The Vicar collected taxes for the Church of England, a tithe being approximately 10%. — A.B. & M.C.

Disadvantages of Vineyards

The vine, indeed, has the advantage of being a large perennial plant, and of receiving some part of its nourishment below the staple, but it also has disadvantages. The soil of the vineyard never can have a true summer fallow though it has much summer hoeing for the vines live in it, and all over it all the year. Neither can that soil benefit from manure, because though by increasing the pulverization it increases the crop, it spoils the taste of the wine. The exhaustion of that soil is therefore supplied by no artificial help but hoeing and by all the experience I have had of it, the same cause will have the same effect upon a soil for the production of corn, and other vegetables, as well as upon the vineyard.

CHAPTER EIGHT: OF WEEDS

Weeds defined: any plant that is different from those which are sown as crops; those unsown crops in natural reservation are not weeds

Plants that come up in any soil that are of a different kind or species from the sown or planted crop are weeds.[170]

Weeds eat what food dung and tillage have provided, and are usually unwelcome, but sometimes can be

Botanists deny that there are any weeds that cause no harm, and classify all weeds as noxious, unprofitable and hurtful. The farmer finds in a crop noxious weeds that come up like flies or uninvited guests, devouring what food the dung and tillage has provided for the crops' sustenance.[171]

Not all weeds are equally bad, and some are beneficial

All weeds are pernicious, but some much more than others.[172] Some do more injury and are more easily destroyed, some do less injury and are harder to kill, some do much injury and are very

[170] Plants in natural reservation are not weeds, even if they are not sown. –A.B. & M.C.

[171] Some weeds, while uninvited, are welcome anyway. We divide these into five classes of beneficial weeds:

1. Those which are edible or otherwise more valuable to human industry than the damage that they cause by eating the food intended for the crops. In example, wildflowers can provide extraordinary income to the farmer who allows them to remain in the bed of vegetables if the farmer takes the time to cut them and bring them to market as bouquets.

2. Those which provide habitat, including hunting blinds, to the creatures that would defend the crops from their natural enemies (including enemy plants, animals and microorganisms), resulting in less loss due to the protection than they cause by requiring weeds that eat the food of the crops. Especially with some of the smallest animals, and especially with the invertebrates, species can be adapted to use only one species of plant or otherwise have very specific environmental requirements.

3. Those which the farmer is attempting to domesticate for future crop production: the farmer must have some wild seed stock for breeding purposes.

4. Those which increase resources for crops more than they take. An example is found with the purslane, which eat little food and water, but provide a mulch in dry areas that retains moisture – and at the same time provides a saleable crop that is highly valued and nutritious for human and animal consumption.

5. Those whose benefits to the humans are invaluable through financial assessment. The beauty of a field is important to many farmers, and the wild mints or asparagus that sometimes find their way among the crops are a pleasure worth more than their market value.. –A.B. & M.C.

difficult to kill. The hardest to kill are those that will grow and propagate by their seed and every part of their roots (such as couch grass, coltsfoot, meliot, fern, etc).

Some are hurtful only by robbing legitimate (sown) pants of their nourishment (as all weeds do)[173], others will lessen a legitimate crop by robbing and spoiling it with their nauseous scent and flavor (such as meliot, wild garlic, etc.).[174]

[172] The ants will "weed" their fungal farms of undesirable fungi, not only to benefit their domesticated fungus, but to protect themselves: some of these undesirable fungi produce toxins that would damage their colony.

However, another lesson is gained from the mosquito, itself a noxious animal. These animals are noxious because they spread disease and harm people. However, they are also essential pollinators, undertaking the pollination of plants during seasons other insects will not. The destruction of mosquitoes would be very harmful indeed. But, as they cannot be held in a reservation that still allows them into the fields, we have to reserve from their territory only that which people are occupying: the blood eating members of this essential pollinating species may be thwarted by wearing mosquito netting.

A third lesson comes from those modern monsters created by humanity through genetic manipulation and pose severe and immediate threats to the farmer. Some of these engineered plants and animals will exterminate or sterilize all the crops in a field, and all the wild plants in the surrounding lands. These monsters may, justifiably, be warred upon. –A.B. & M.C.

[173] In a poorly managed field, even sown crops can compete with each other for resources. In a well managed field, the sown crops can enjoy a beneficial symbiotic relationship with the weeds, enjoying the water and protection of their native hosts. This is more critical in deserts, which require the defense of crops against the harsh sun. In temperate areas, less protection is required. Typically in deserts, plants are paired in twos or threes in known symbiotic relationships: an example is the corn/beans/squash trio. However, we sought to undertake a trial to learn whether plants would as readily undertake a symbiotic relationship with weeds.

In a test plot, we let the weeds grow in the beds while keeping our aisles well tilled and have gained not only a striking picture of our squashes growing easily among the grasses and thistles, but also the understanding that Lovelock's theory is correct, and that the more life in a field, the less environmental pressures effect that life. That said, we would prefer to keep the weeds in reservation, and plant more useful crops together.



We also learned through these trials that weeds can be important to our crops. In desert conditions, they shield our crops from the hot sun and give them water, improving yields (as would domestic crops planted in their place). Under all conditions, they provide necessary habitat to the friendly creatures that defend our crops against being eaten. Many of them are edible or valuable for sale. They provide good green manure. They hide our crops from the larger herbivores that would eat them if they could see them, and discourage all herbivores by the threat of a carnivore hunter hiding in them.

While reservations are certainly important, some weeds are important to retain in the rows.–A.B. & M.C.

[174] To test this, we planted (and continue to plant) our garlic among our crops and have never had the flavor imparted to any other plant. A shame, as we like garlic! However, dairy farmers can flavor the eggs and milk of their farm by feeding their animals certain herbs. Weeds in a pasture would have an impact on production, though it might be a positive one. We provided volunteers with eggs from chickens raised on pure grain, on mixed pasture, and fed garlic and turnips, and found that, without the volunteers knowing which one they were eating, they preferred the ones with the stronger flavors. –A.B. & M.C.

Trees can be weeds too, and should be managed as such in orchards, forests and in integrated field/orchard productions

A tree of any sort will spoil corn all around it; half an acre of turnips was spoiled by a single tree![175] Trees rob as weeds do, not because of their shadow (there is an equal amount of damage on the southern side as on the northern), nor is it by their annual leaf dropping (the same damage occurs on the side without boughs as on the side with boughs). It is, logically, the roots which are starving the crops.

Proving that weeds eat the food of crops, proving the importance of so-called pest and noxious species, proving the ability to control pests and noxious species through targeted natural predation

The following experiment demonstrates that weeds starve sown plants by robbing them of their food, not of space (as some authors might imagine).

Let three beds be made of the same soil, equal and equally prepared. Sow them all in the same sort of corn. Let the first be kept clean from weeds, in the second, let a quantity of weeds grow along with the corn, and in the third, stick up a quantity of dead sticks, greater in bulk than the weeds. It will be found that the produce in corn in the first will not exceed that of the third bed, but that the second bed (where the weeds are) will produce less in proportion to the quantity of weeds in it.[176]

The sticks, having done no injury to the corn, show that there might be room enough in the bed for company to lodge if only the guests would forbear to eat or, (as travelers in Spain do), bring their food with them to the inn, or (which amounts to the same thing) if the weeds, upon arriving at the inn, found a dish disagreeable to the palate of the corn and agreeable to their own that they might feed without robbing the corn of its supper. Then weeds would be as innocent as sticks, which take up the same room as weeds.

The quantity of nourishment that weeds rob the corn of is not in proportion to their number and bulk, but to their own eating habits and metabolism (as appears by the example of Charlock and Turnips mentioned in the Chapter on the Change of Species). It is needless to compute the value of the damage that weeds do, since all experienced husbandmen know it to be very great and would

[175] This is probably due to an improper spacing allowed for the tree. Weaver and Clements even noticed that grain can stunt the growth of trees if planted too close to the trees. However, when properly spaced, trees generally improve the profitability and security of a farm's production, and have a very positive impact on biodiversity and biodensity. Their yield of fruits, nuts, vegetables, animal feed, mulch, fuel and other products are equally welcome.

In large forests or orchards, there are often "weed" species of trees, and these should be managed as they are with crops. Reservations are their best home, but some "weed" trees are better for the farmer in the rows. –A.B. & M.C.

[176] It is strongly recommended to undertake this kind of trial because it teaches both the importance of weeds, and the importance of too many weeds. In keeping weeds in the beds, ensure that their density does not become overmuch: just as you would not plant your crops too close together, do not allow your adopted weeds to be too close either. –A.B. & M.C.

unanimously agree to extirpate their whole race entirely, as in England the people have done with wolves (who, though much more innocent than weeds, are less rapacious!)[177]

[177] Rachel Carson's example of the extermination of coyotes leading to an explosion of the vermin whose population they were controlling is brought to mind here: the actual damage from wolves is less than their benefits, and the real danger to people (or children), domestic animals or other property is typically less than the cost of their extermination

Reuters News Agency reported on August 1, 2005 this exact phenomenon.

WASHINGTON (Reuters) — The loss of once-plentiful wolves in a part of Canada's west allowed the elk population to mushroom, pushing out beavers and songbirds and showing the importance of top predators, Canadian researchers said on Monday.

Although scientists have long noted that the loss of even one species can have profound effects, the report is one of the first large-scale studies to show clearly the widespread consequences of losing a predator at the top of the food chain.

Mark Hebblewhite of the University of Alberta, and colleagues studied what happened in "a serendipitous natural experiment" when wolves returned to part of the Bow Valley of Banff National Park in Alberta. Wolves were driven out in the 1960s "because that's what we did then," Hebblewhite said. "The first wolf pack recolonized the Bow Valley of Banff National Park in 1986. High human activity partially excluded wolves from one area of the Bow Valley, whereas wolves made full use of an adjacent area," the researchers wrote in their report, published in the journal Ecology.

Willow trees, river-loving birds called willow warblers and American redstarts, and beaver dams once were common in Bow Valley and surrounding areas. But in the areas where wolves remained scarce and elk populations mushroomed, these plants and animals were less common.

The wolves clearly had a major effect on elk. Elk populations were 10 times as high in areas where there were no wolves, Hebblewhite's team found. This meant that elk could be found in suburban backyards, and sometimes on hiking trails. "Seven people are sent to hospitals every year on average by getting into a fight with an elk," he said. "They are 250 kilograms (550 pounds) on average so you don't want to get into a fight with one. But being a park they couldn't just go willy-nilly shooting elk and as a society we have advanced beyond wildlife management by just shooting things."

The elk browsed on tender young willows, leaving little for beavers and willow-dwelling birds. Aspen trees seemed less affected. "We also found that as elk populations climbed, active beaver lodges declined, probably because beavers could no longer find sufficient trees with which to build their dams," Hebblewhite said in a statement.

But in the parts of the park where wolves returned, the elk populations in affected areas fell and willows were coming back. While other predators such as grizzlies might have played a role, Hebblewhite's team noted, bears were never completely driven from the park while wolves were. "Yes, wolves are ecologically important. It (the study) bolsters the importance of conserving species like wolves and other top carnivores," Hebblewhite said. Copyright 2005 Reuters.

Beyond willows and beaver, the farmer can see a direct impact on the flora and fauna of their farms and ranches when wolves – or any other undesirable creature – is destroyed. What is the implications of disaster associated with the destruction of a plant?

Clearly, what farmers desire is not the extermination of a problem species, but its control.

Doctors Dr. W. Wyatt Hoback and Dr. Kerri M. Skinner of the University of Nebraska at Kearney and Dr. Robert K.D. Peterson and Dr. Sharlene E. Sing of Montana State University have combined their efforts to form RELEASE (Risk Evaluation Learning to Explore Alien Species

Establishment) to help improve the understanding of the decision-making process that precedes the release of biological control agents.

Besides providing online lessons in identification, ecology, entomology and other sciences (at http://cgi.unk.edu/hoback/home.html), the Doctors provide information on successful alien species establishment.

In example, they point to the Asian Leaf Beetle to target Saltcedar (Tamarix spp.), a non-native, invasive tree that has been problematic in most southwestern states and some north-central states. Saltcedar has infested about 1.5 million acres, increasing its range by a rate of about 50,000 acres per year. It prefers riparian areas, especially waterways with receding surface water, and results in $127-$291 million in damages annually.

"The risk assessment for this non-native biocontrol agent release has been one of the most extensive and complete analyses to date. Research and testing of host-range parameters were conducted from 1992 to 1996 in Europe and Asia at cooperating facilities, along with select species tested in quarantine facilities at Temple, Texas," encourage the Doctors.

Before making their recommendation, they test the alien species for host specificity and non-target effects (on phylogenetically related species, species in close proximity of infested areas, species with similar habitat requirements, and species of agricultural or horticultural concern). Their tests utilize several experimental designs, including no-choice, choice and multiple choice for larva and adults. The survival of beetles and the extent of damage was measured.

In their tests, they found that the saltcedar was fed upon by both adult and larval stages, which enjoyed foliage, twigs and first-year shoots especially. This caused the gradual dieback of stems, death of small plants and limited regrowth.

Expected results of beetle release are decreased saltcedar stand density, reduced saltcedar size (foliage cover), increased wildlife activity, decreased soil salinity, and restored groundwater.

And, proving their research, a northern Nevada release site has had considerable success with the biocontrol beetle release. In 2002, there were 5 acres noticeably affected by beetle defoliation, and in 2003 this increased to 500 acres. By 2004, the beetles damaged saltcedar trees in the surrounding 50,000 acres.

And, best of all, since the open field releases in 2001, there have not been any identified non-target effects of this biocontrol agent. Similar success has been had with the decapitating fly controlling the fire ant, and the thistlehead weevil controlling the musk thistle.

In undertaking risk assessment to learn whether a species should be controlled (or if any action – even beyond pest management – should be undertaken), the scientists draw an example surrounding a salt shaker in a classroom. 11 Tablespoons would be fatal to a person weighing 150 pounds. This threat is real, but risk assessment is required before taking action to prevent death. First it is important to understand both the effects of exposure and the methods of exposure.

Analysis of how the salt could kill someone (exposure through ingestion, skin contact, inhalation, etc.) yields understandings of how to prevent that catastrophe, and might also illuminate the hazard of the shaker itself (which, if applied incorrectly to the body, could also be lethal). When these potential exposures are understood, probabilities of their occurrence can be calculated based on experimental or natural data.

The Doctors fall short of requiring an examination of requiring a financial analysis to determine whether it makes sense to prevent death by salt (or shaker), understanding that when lives are on the line, money is of little consequence and, in our opinion, this demonstrates uncommon ethical and moral fiber, and a loyal public service. The cost of a person's life (or the life of any other

If we consider the crops that weeds utterly destroy and those which they extremely diminish, and that very few crops can escape without receiving injury from weeds, it begs the question whether the mischief weeds do to the corn is not as great as the value of the rent of all the arable lands in England!

Controlling weeds through tillage, even though their seeds may remain dormant decades, addressing objections that tillage makes more weeds

But alas! It is impossible to exterminate weeds with anything but the horse hoeing husbandry.

The seeds of most kinds of weeds are so hardy that they may remain viable for many years. The seeds of the lethean poppy (also called red weed) can lay dormant more than 24 years. I have seen this, and many other sorts of weeds, come up very thick with the first plowing after the land has laid unplowed for an age. Weed seeds may last ages in the soil, and are not killed until they grow up and sprout—which few of them do unless the soil is plowed. Then, they will ripen among the sown crop, to propagate and continue their species by shedding their offspring in the ground (for they are generally ripe before the corn) to return with the plowing of the next crop.

This is how they perpetuate their savage, wicked[178] brood from generation to generation: their seeds never all come up in the same year, unless the land is very often plowed. The weeds must have their exact depth, degrees of moisture and heat to germinate. Those that do not have their requirements will not sprout and will wait until the time is right. The usual number of plowings is not enough to bring them all (or even the greatest part of them all) to grow. Every successive generation of weeds adds to the number of dormant seeds in the soil until the seeds compose the bulk of the staple of the land!

The best defense against these enemies hitherto known is to perform a good summer fallow. While this may work, it depends on the weather to destroy most of the weeds and, even when the weather is cooperative, some seeds escape the year's attack. Weeds can endure variations in heat

living creature) cannot be quantified by money, even if their value as a resource to industry can be.

While it is impressive that these aliens have successfully controlled their target, it is more so that they have not complicated the ecology further by affecting other creatures. A zero-tolerance for risk, while impracticable, is sometimes necessary when the lives of humans and other living plants, animals and microorganisms are involved. Life is precious in all its forms, and it is better to do no harm than to undertake something that will knowingly further destroy the delicate balance of an ecology. While aliens are not uncommon, and species naturally migrate and disperse throughout the planet, the rapidity at which strange new creatures are being accidently and widely introduced has caused mayhem to the local environments that receive them.

Change is best when it happens slowly, and the noble efforts of the RELEASE Group to help speed the stabilization of the biosphere are better than could be expected. By providing to industry another tool to rely upon in the control of pests besides chemicals, the RELEASE Group has performed a service to posterity. The risks of further ecological collapse due to alien introduction are small when compared against the toxicity of many of the too-commonly used chemical control agents. Besides, the cost of alien introduction is so small (and is, on top, a nearly one-time expense) that the savings to private and public purses is enormous.–A.B. & M.C.

[178] Indeed, the French call weeds *les herbes savages* or *les mechantes herbes*!

and moisture, and even when conditions are ideal for their germination, some seeds will wait until the next year anyway.

A summer fallow can have no effect upon weeds except to prepare the remaining seeds for the following year of vigorous growth, and a plentiful increase in the year after. Two successive years of summer fallow would be required to do more damage, but few farmers can afford two years of summer fallow. And, even if the farmer did perform two years' summer fallow, the following year, when they applied manure to the crops, the manure would bring with it fresh reinforcements to the depleted weed stock.

Another remedy for weeds, whose "cure" is often worse than the disease, is weeding among the corn. By hook or hand, the weeders cut some weeds (such as thistles) only to find that they sprout up again like Hydra, with more heads than before! And, if the weeds are cut after they are full grown, while they don't sprout up again, it is like shutting the stable door after the steed is stolen: the full grown weeds have already stolen food from the crop.

Hand weeders often do as much damage to the crops with their feet as they do good by cutting or pulling out the weeds with their hands. And yet hand weeding can sometimes cost a farmer twelve shillings per acre (before accounting for the damage done to the farmer's wheat). And, for all this cost, some of the weeds escape and allow a new generation to grow in next year's corn.

This new Horse Hoeing Husbandry will make an utter riddance of all sorts of weeds[179], except such as come in the air[180]. As long as this management is properly continued, there is no danger to be apprehended from weeds, and confutes the old error of equivocal generation, had it not already been sufficiently exploded by the demonstration of Malpighius's experiment. If weeds were brought forth without their proper seeds, hoeing could not hinder their production when the soil was naturally inclined to produce them.

The belief of that blind doctrine might probably be one of the causes that made the ancients despair of finding as great success in hoeing as there now is demonstrated. If they had not believed in equivocal generation and other falsehoods, they might have perhaps invented and improved the Horse Hoeing Husbandry, and the instruments necessary to put it into practice.

[179] A very large and pernicious perennial weed known as burridge (with a blue flower) infested a piece of land for time out of mind. However, the Horse Hoeing Husbandry has destroyed it utterly, and not one of the species has been seen in the field for the last seven years.

[180] The seeds of some weeds are suspected to come in the air, as the grass that grew in the time of the plague. But the grass might come from seeds in the dirt, brought thither by the feet of people and cattle, and by the wheels of coaches, carts carrying hay or other ways. Continual treading keeps it from growing, and when the treading has ceased, the seeds furnish the streets with grass. I have observed on the floors, two stories high, of a lone, ruinous, uninhabited house, being long unroofed, a sort of plant growing very thick. I think it was pimpernel, and believe that its seeds did not come thither in the air (the seeds of pimpernel are too heavy to be carried on the wind very far) but in the sand which was mixed with the mortar that had fallen from the ceilings. It is likely that there were few seeds at first, but these, ripening for several years, shed their seeds annually until the floors became very thickly planted all over.

Jethro Tull's Supplement

Tillage Does Not Make a Field Weedy

The seeds of Lethean poppy (called red-weed) have lain dormant 24 years (the land being during that time in sanfoin), and then at the first plowing they came up very thick, and so will many other sorts of weeds, when the ground has lain untilled for an age.

The seeds of some weeds may be suspected to come in the air, as the seed of the grass that grew in Cheapside[181] in the time of the plague; but it might come from seeds in the dirt, brought there by the feet of people and cattle, and by the wheels of coaches, carts carrying hay or otherwise: continual treading might keep it from growing, and when the treading ceased, it is no wonder the seeds should furnish the streets with grass.

And I have observed on the floors, two story high, of a lone, ruinous, uninhabited house, being long uncovered, a sort of herb growing very thick. I think it was pimpernel, and believe that its seeds did not come there from the air; but in the sand which was mixed with the mortar that had fallen from the ceilings. It is likely there were few seeds at first, yet, these ripening for several years,

[181] Cheapside is a common English street name, meaning 'market-place', from Old English ceapan, 'to buy' (cf. German kaufen, Dutch kopen). There is originally no connection to the modern meaning of cheap ('low price', a shortening of good ceap, 'good buy'), though by the 18th century this association may have begun to be inferred.

Cheapside is a street in London, in the ward of Cheap, that links Newgate Street with the junction of Queen Victoria Street, Cornhill, Threadneedle Street, Princes Street, Lombard Street and King William Street. It was one of the principle produce markets in London: Many of the streets feeding into the main thoroughfare are named after the produce that was originally sold in those areas of the market, for example, Honey Lane, Milk Street, Bread Street and Poultry. In Medieval times, the royal processional route from the Tower of London to Westminster would include Cheapside, and was usually a route for visitors of the State. During the reign of King Edward III (in the 1300s) tournaments were held in adjacent fields. Meat was brought in to Cheapside from Smithfield, just outside Newgate. After the great Church of St Michael le Querne, the top end of the street broadened into a dual carriageway known as the Shambles (referring to an open-air slaughterhouse and meat market), with butchers shops on both sides and a dividing central area also composed of butchers shops. Further down, on the right, was Goldsmiths Row, an area of commodity dealers. From the 14th Century until the Great Fire, the eastern end of Cheapside was the location of the Great Conduit.

During the plague, so many people died and so little commerce was undertaken that grass began to grow on this busiest of London streets. Poor records prohibit an accurate estimate of the number of dead, but where accurate records exist, estimates indicate that between 20% and 80% of the population died: some areas were harder hit than others, and some regions were entirely depopulated, if not by death, than by those fleeing the disease. The Plague occurred in several bouts, and each one was similarly severe. The Great Plague of London (of 1665-1666) was one of the last outbreaks of the plague, and while not very deadly, did scare the people enough to reduce commerce and temporarily depopulate regions. It was accompanied by the great fire of London, which might have reduced the deadliness of the attack. –A.B. & M.C.

shed their seeds annually until the floors became all over very thick planted: besides, hay-seeds and pimpernel are too heavy to be carried far by the air.[182]

Hand weeders do more harm with their feet than good with their hands, horse hoeing rows and aisles does only good

Hand weeders often do more harm to the corn with their feet than they do good by cutting or pulling out the weeds with their hands. And yet I have known this operation sometimes cost the farmer twelve shillings an acre, besides the damage done by treading down his wheat! And after all that expense, a sufficient quantity of weeds escape to make an increase in the next crop of corn.

The new hoeing industry in time will make such an utter riddance of all sorts of weeds in a field, except such as come in the air, that as long as this management is properly continued, there is no danger to be apprehended from them, which is enough to confute the old error of Equivocal generation, had it not been already sufficiently exploded ever since the demonstration of the Mapighiuse experiment. For if weeds were brought forth without their proper seeds, the hoeing could not hinder their production where the soil was inclined naturally to produce them.

Birds also spread weeds, but the weeds in fields under the Horse Hoeing Husbandry are not easily restocked

The hoeing also does little to prevent the spread of weeds by birds, which is the most common manner of transporting the seeds of vegetables from field to field against the consent of the owner. For birds, whether great or small, do not care to eat their pray where they take it, but generally choose some open place for that purpose. It is, I am persuaded, by this means chiefly, that a vineyard or field made ever so clean from grass, will, in lying untilled a few years, be replenished with a turf of that neighboring species of grass which best suits the heat and moisture of the soil: yet there are some species of seeds that birds (at least such as frequent the place) do not eat, or else surely the burrage-weed would have appeared again in my field in some of the many years since the hoeing extirpated it there, for it grows plentifully in the unplowed way adjoining thereto.

Objections of Equivocus and, in response, further arguments against spontaneous generation of weeds

I never heard that any author has been dissatisfied with this experiment, except Equivocus, who (unless my memory deceives me) has falsely quoted it; for he leaves out the latter part of it: that when seeds were put into the glass, the earth produced them into plants very soon.

His objections against the fairness of this experiment are two, that the lawn (I think it was) deprived the soil of some part of the powers which he affirms would produce plants spontaneously. And that the time the soil was in the glass was not sufficient for the effect of those powers.

To answer the first objection: what he calls a fine linen cloth was only to keep out seeds from being conveyed into the glass by the air. The sun's influence was rather increased by the refraction through the glass: air, rain, dew, and all sorts of particles of the atmosphere, might enter through the

[182] After much deliberation, the repetition of this paragraph was permitted as it provided in its new context new insights. –A.B. & M.C.

lawn cover: it was plain, that nothing was wanting for production but seeds, which, when they were thrown in, were produced with no other helps than the earth had while nothing was produced. And we see plants come up under a north wall from earth where upon the sun does not shine; and even in places where there is not so free an air as that earth in the glass enjoyed.

As to the second objection: Equivocus owns the glass stood a long time, but it seems it was not long enough for the earth in it to produce plants without corporal seeds. I would have him let the world know how long a time he requires earth to remain in that manner before determining that point against him.

Equivocus seems to object against that experiment for the fairness of it and to show how much he abhors every fair experiment that discovers truth, he quotes most unfair ones against it.

His first of this sort is that when earth taken out of cellars, and exposed on the top of a house, plants as such that grow in the neighborhood will come up in it. What can be hence inferred in proof of Equivocal generation, unless we are sure that no seeds of those plants were in that earth when in the cellars, and unless the top of the house was so high as to be above the reach of winds and birds that could carry seeds there?

The wormwood coming up amongst the rubbish is no fairer an experiment than his other, for though it came up in the spring when there are no seeds to shed, the seeds might be carried thither in the autumn or in the winter, for wormwood holds some of its seed even in winter, when some sorts of birds (as goldfinches) being hungry take it out, and sometimes carry it off to eat it, and love to peck it on dry ground. And the rubbish of a house seems a proper situation for their feeding on it. And they generally leave some seeds behind them in such places. And yet Equivocus is so vain as to affirm, that "this is a plain instance, that those plants did not derive their original from real seed."

As to his instances of mustard seed, furze, broom, charlock, and innumerable other species of plants which might be found, which Equivocus and some of the most ignorant of the vulgar imagine to be produced from a fortuitous concourse of particles, and not from real corporeal seeds? They are answered by Equivocus himself in his Essay of May, p. 60, as follows: "that there are many seeds which lie long in the ground without any visible signs of germination is not to be disputed." And I see no impossibility against their having lain so from the Biblical Flood, if not from the creation of the world (I mean such of them as lie deep in the earth, and have never been exposed to the sun, air, etc.); however, there is less impossibility of that, than of their being generated by a fortuitous concourse of atoms and particles.

Yet in Equivocus's defense, a seed that by its smallness is invisible to the naked eye contains in it an almost infinite progeny of its own species, and is a little world whose creation is as miraculous a work of infinite wisdom as the great world; and one might as well be produced by fortuitous concourse as the other.

Nature is regular and geometrical in all her works; hence each seed produces no other species of plant but its own; but blind chance is irregular, and if it were possible for it to produce a plant, it would be of some other species than those produced from seeds. Therefore, I think, no reasonable man can suspect any plant to be generated by a fortuitous concourse of particles, unless he is satisfied of its being a new species that never appeared in the world before it; neither would any two spontaneously-generated plants be of the same species, not being the offspring of parents proper to each.

Indeed, in this respect of singularity (of singular falsehood, singular ingratitude, and singular inhumanity) different from the common species of men, Equivocus himself seems a stronger argument for spontaneous generation than any he brings! And as he founds his faith of that blind doctrine on the opinion of heathen authors, who held it the same for animals as for plants, and that

many of the former were generated from putrefaction and corruption[183], there seems no fortuitous concourse of particles so likely to have produced Equivocus as of such an unsavory composition mentioned in his Essay of April, p.p. 72-74. He says, "ordure, dung, and air, actuating on one another may produce," etc. – I say, *Sterquilinium Equivocum*[184].

That mushrooms are generated without seed in the manner pretended (from rotten dung that smells of mushrooms) is a very fallacious account, since they are known to bear seed in their gills, and the Paris gardeners rub old dry mushrooms on the dung, which produces the young ones, by such rubbing the seed comes out of the gills.

And when Equivocus, in his Essay of August, p. 180, describes the manner of making a mushroom-bed, he directs, that it be set with cakes of dung that smell like mushrooms, and then he says there will afterwards "come up mushrooms enough especially if the earth of the mushroom bed be watered with the water wherein mushrooms, which sprung up every September, are washed."

Here Equivocus's lower class of readers must renounce their sense, as well as their reason, in order to free themselves from all suspicion of mushroom-seeds being in those cakes, or in that water, before they can be able to perceive the cogency of his arguments for the Equivocal or fortuitous generation of plants, without real corporal seeds.

As neither Equivocus, nor any other advocate of this blind doctrine, make any distinction between the generation (or production) of plants that bear a large seed, and those that bear a small seed, I hope it may be sufficient to convince them of their error if it can be demonstrated that plants which bear a large seed are not produced Equivocally: for which purpose, let an experiment be made, which shall not be liable to the objections Equivocus makes (though I think unjustly) against that of Malpighius, in the following manner: let there be a very fine wire sieve, such as is used to sift tobacco, though which let be passed what quantity you please of earth of any sort and from any country; set it without a cover in the open air, where no birds come, especially great birds; and this may be in some place where people are always present in the daytime: let it thus stand a whole year, or as much longer as you will, and stir it as often as you think fit. Then if no bean, pea, fir, or other plant, bearing such a large seed appears in it; or in case small birds are kept from that soil by a net, or otherwise, than if no plant, the smallest of whose seeds are too large to pass the meshes of that sieve, come up, I believe every man of sense will be confirmed in the doctrine of Equivocal generation of all vegetables.

Yet there is no occasion to make this trial of such plants whereof the real corporal seeds, or their husks, at the coming up may be discovered by the naked eye, or by help of a microscope, as they may be at the first coming up of most sorts of plants.

Many more arguments might be brought against Equivocus on this point; but *absurdas opinions accuratius refeltere stultum est*[185]. And I think no opinion can be more absurd than this of Equivocus.

The belief of that blind doctrine might probably be one of the causes that made the ancients despair of finding so great success in hoeing as now appears; or else, if they had true scientific insight, they might perhaps have invented and improved that husbandry, and the instruments necessary to put it in practice, for the prevention of weeds.

[183] Such as the ancient belief that bees originated from the rotting corpse of an ox. –A.B. & M.C.

[184] Uncertain, doubtful, questionable dunghill. –translation by Aaron Brachfeld

[185] Absurd opinions refute themselves best. –translation by Aaron Brachfeld

Supplement of the Fifth Edition

Weeds are good neighbors, if not always good bedfellows (though they sometimes are)

When we were conducting our trials on weeds in the beds (a picture of which was provided earlier in this chapter), our farm seemed overrun by weeds! "Where are the crops?" visitors (and landlords) sometimes asked. Before answering and showing the visitors where the crops lived, we were quick to point out that this is the same question the animals who would eat our crops would ask. The larger animals can't see the crops, and move on to someone else's garden...or eat the weeds that are more visible. The smaller animals (such as insects, mice, rabbits, etc.) that do not have such a problem seeing the crops (because of their size, these smaller animals are forced to take a close look at everything they happen upon), also are discouraged from eating the crops. The weeds provide habitat for carnivorous predators...and the animals who would eat our produce know this.

Yet it is not necessary to allow weeds to grow among the crops. A rabbit will fear the snake or cat hiding in the bush nearby; a fearless aphid is eaten by the ladybug living in the same bush. Spiders are able to craft great webs across the gaps, and foxes find ideal ambushing conditions. This protection afforded against animals that would eat our crops comes with the additional benefit of protecting the crops against the elements.

The fact is that weeds are good neighbors, though not always good bedfellows (though they sometimes are). With experience through experiments, the farmer can learn when to tolerate weeds, and when to not. Only through experience can we learn our friends from our enemies; only a fool presumes friendship or enmity without experience.

Practical Horse-Hoeing Husbandry

I hope these hints may be improved for the abolition of old errors and the discovery of new truths.

To the decision of the reader must be left all that is disputable. Truth is like gold, which the more it is tried the brighter it appears, being freed from dross...

...to be thus examined is the chief design of publishing this essay on tillage and vegetation.

—Jethro Tull

CHAPTER NINE:
REMARKS ON THE BAD HUSBANDRY THAT IS SO FINELY EXPRESSED IN VIRGIL'S FIRST GEORGIC

It is impossible, in general, for any method to be worse than Virgil's

A recent commentator upon Virgil's *Second Georgic* says in the preface "he is certain the husbandry of England in general is Virgilian, which is shewn by the Paring and Burning the Surface; by Rastering, or Cross Plowing; and that in those Parts of England, which the Romans principally Inhabited, all along the Southern Coast, Latin Words remain to this Hour among Shepherds and Plowmen in their Rustick Affairs; and what will seem more strange at first fight to affirm, tho' in Fact it be really true, There is more of Virgil's Husbandry put in Practice in England at this Instant, than in Italy it self."

It is my opinion that the Italians, in changing Virgil's field husbandry have acted more reasonably than these English who retain it because I think it is impossible for any method in general to be worse than Virgil's.

Horse hoeing husbandry different from Virgil's in all respects, and may be called anti-Virgilian

My method differs from Virgil's in all respects and may be called anti-Virgilian.

The false philosophy of sat erit (it is sufficient)

Pingue solum primis exemplo a mensibus anni
Portes invertant tauri: glebasque jacentes
Pulverulenta coquat maturis solibus astas...
officiant latis ne frugibus herbae

[186]Straight let the vigorous steer
Turn the rich furrow, in the new-born year
And summer's heat with ripening sun's pursue
The sluggish glebe, and all the clod subdue...
Lest the weeds the smiling blade withstand

[186] I should acknowledge that all the English verses in this chapter were transcribed from an anonymous translator. I chose to make use of these because I thought they came nearer to Virgil's meaning than any other translation I had seen. [This applies to only those translations held in the text itself, not in the footnotes. –A.B. & M.C.].

This is Virgil's reason for plowing rich land betimes and shows that the ancients believed the only reason for tilling and hoeing was for killing weeds.

At si non suerit tellus saecunda, sub ipsum
Arcturum tenui sat erit suspendere sulco...
Sterilem exiguus ne deserat humor arenam

But if not fat the soil, it will suffice
When bright Acturus mounts the purple skies
To skim the surface with a gentle share
And lift the furrow lightly to the air...
Lest moisture desert the barren sand

Virgil directs that poor land should be plowed late for fear that moisture should be dried out of it.

And yet poor land has more need of frequent and early plowings if all its moisture is not to be exhaled for want of being opened: without tillage and hoeing, the poor land can receive little water from the atmosphere. The later it is plowed, the drier it will be.

The philosophy of "sat erit"[187] is therefore a great mistake.

The false philosophy of tenui sulco (shallow furrow)

The land that is sterile requires plowing as deep as possible. The poorer the soil, the less reason there is to leave any of it unplowed. Shallow plowings, even if it makes the earth fine, loses most of the benefit that the atmosphere brings to the ground because the soil is so hard below the tillage that it will not suffer the atmosphere to enter deep. The shallow tillage lets the moisture and atmosphere escape during the day, keeping the soil drier and poorer.

The false philosophy of burning fields

Sape etiam steriles incendere profuit argos
Atque levem stipulam crepitantibus urere flammis

It profits often to fire the fruitless ground
And thirsty stubble crackling all around

Virgil directs the burning of stubble on rich land and burning the turf itself on barren land, because barren land has no stubble on it to be burnt. Such poor land is better enriched by plowing it. The salts that are left after burning will produce a few crops, but tillage causes the land to produce many more. Yet the custom of burning stubble on the rich plains about Rome continues to this time.

[187] Sat erit means, "it will be sufficient," "it'll do." Translated by Justin Walker and Aaron Brachfeld.

The only benefit to burning stubble is that it prevents the stubble from being an encumbrance to the next planting and the ashes (together with the dead bodies of the animals killed by the flames) becomes a sort of manure (though a very poor one, and very little in quantity) for the soil[188].

As for burning the soil itself on barren fields (especially those with a shallow staple), there are no benefits. It is a pernicious practice, carrying away so much of the best part of the soil that it has been not only (as far as I can be informed) wholly abandoned in Italy, but in most other countries where the owners of land have any regard to posterity. It certainly destroys those thin, poor fields and, after a few crops, renders them wasted.

Why does Virgil argue for the burning of land? The reasons Virgil offers for explaining the cause of this short improvement are, as abstracted from the poetry, entirely unbecoming the character of a scientist. Scientists assume laws of causative reaction[189]. Virgil's assumptions are so contrary to one another and so jarring among themselves that all of them are false!

Sive inde occultas vires, et pabula terrae
Pinguia concipiunt

Whether from thence by Nature's secret laws
Fresh nourishment the earth, and vigor draws

This is far from being true. Fire, instead of giving any sort of strength or nourishment to the soil that is burnt, carries strength and nourishment away, bringing nothing to replace them. The great decrease in weight of burnt soil shows how much is missing, and I am disappointed to find that Mr. Evelyn should think that an intense incineration of the soil increases the weight of the soil: even stone burnt to lime loses a third part of its weight by the incineration and soil, being even more sulfurous, loses more of its weight by being burnt and visibly emits more smoke!

Sive illis omne per ignem
Excoquitur vitium, atque exudat inutilis humor

Or that the latent vice is purged by heat
And the redundant humors waste in sweat

There was no "vice" in the ground to be boiled out—unless it was that the land was stocked with grass and wanting tillage! Had there been moisture in the ground, it would not have burnt, but required drying out before the fire could operate.

Seu plures calor ille vias et caeca relaxat
Spiramenta, novas veniat qua succus in herbas

Or, that the flames unusual tracks explore
Relax the grit, and open every pore
Whence the genial moisture hastens through the Earth

[188] Though more reason is not needed, other reasons not to burn fields: it decreases biodiversity, both within the soil and above it; burning humus does not build fertility. –A.B. & M.C.

[189] Tull's words were "rerum cognosere cusas." –A.B. & M.C.

Slides to the root, and cheers the tender birth

Fire does, indeed, relax and open the earth...so and releases all its fruitful breaths out of it! Fire makes room enough for the water to reach plants, but the mischief of fire is that it leaves no water for them.

Seu durat magis et venas astringit hiantes
Ne tennes pluvia, rapidive potentia solis
Aorior, aut Borea penetrabile frrigus adurat

Or that the heat the hollow glebe constrains
Braces each nerve, and knits the gaping veins
Lest piercing wet, or the swift power of day
More fierce, or scorching Boreas [the wind] urge his way

Hay day! This is both contrary to what Virgil said before of relaxing and opening, and to the facts of Truth itself: for, fire having reduced the soil (that it has left and not carried away) to ashes, the ashes are so hollow that rain, heat and cold will easily enter into them, so loose from their cement being carried away by the fire that they will not become hard or dense.

Ashes are so light that it is common for the rain to wash them from the declivity of a hill, for the wind to blow them away from the plain. And it is a demonstration of their sterility that no manner of plant will grow or live in them.

Virgil understood, studied and solved this phenomenon by a positive (and ingenious) "je ne scai quoi," and should have left off with:

Effaetos cinerem immundum jactare per agros

...nor over the exhausted sand
To spread vile ashes with a friendly hand

From observing the effect of these impure ashes, Virgil might have discovered the cause he so unfortunately aims at. The cause of the fertility he observes can be no other than the salt from the ashes being spread upon the remaining unburnt soil and then dividing the soil into an almost infinite number of parts. This division increases the number of internal surfaces described in the chapter on the pasture of plants.

However, for whatever benefit gained by the ashes, if the loss sustained in the waste and diminution of the staple of our poor land in burning it, we would find that these ashes are a very expensive compost! For though two or three good crops are received after this manure (whose salts divide the soil more than common plowing can do), the land becomes even poorer. Yet do not say that the fire will never suffer the land to be equal to unburnt land. With good tillage, in less than a few years[190] the land will recover its fertility.

[190] Within even a few months! —A.B. & M.C.

The false philosophy of harrowing

Multum adeo, rastris glebas qui frangit inertes,
Vimineasque trabit crates, juvat arva

Much too he helps the field, who every clod
With Harrows breaks and drags the hurdle's load

This way of tilling soil with harrows recommended by Virgil demonstrates his husbandry was degenerated from that of the old Romans, who said:

Male subactum agrum qui occandus sit

That field is ill tilled that wants harrowing
—Columella

An even worse device for tillage than the harrow is the hurdle made of vine twigs. This is so puerile an invention that Virgil might have directed it to be drawn by a hobby horse!

Virgil describes this harrowing and hurdling to be of use in sowing once the field has been once-plowed. With this principle included in his *Georgic*, Virgil has amassed together every one of the worst methods of husbandry that could be met with in any age or country.

The false philosophy of cross plowing

Rursus in obliquiam verso perrumpit aratro

Assails oblique, and through cuts again

While the green side of the furrow, which is turned downward by the first plowing, is rotting, the root side of the furrow (now facing upward) sends up blades and stalks of grass from all the joints of roots exposed to the air. Every joint has both roots and stalks included in it, and the open air kills the roots. The stalks are killed for want of air. Thus reversed, the roots become new turf and the old turf, as it decays, nourishes new roots that continue to grow and hold the earth together until they are removed from the reach of the air. But in cross-plowing, not half of the furrows are turned: they are only heaped up upon one another and there the air keeps the grass alive for a long time until they are turned back the same way as they grew before. Only when the grass is dead on both sides will it grow no more.

Cross tilling does not kill the weeds so well as turning the furrows back again into the same places where they were before breaking up, not plowing across the furrows until the third plowing.

Apparently, in Virgil's time, Ceres did not choose her favorites as she does now: she chose them not for their merits and skill, but favored the most slovenly husbandmen with her approbation.

More bad advice from Virgil

Humida Solstitia atque byemes orate sorenas
Agricola...

The Solstice moist, serene the winter sky
For this, ye swains, entreat the powers on high

Here Virgil might have better advised them to remedy, in some measure, the inconveniences of dry weather by frequently hoeing the soil to open it for the reception of the dews that would moisten it, insulating the roots against the cold of the night and the scorching heats of the day. Virgil knew that:

Noctes lentus non deficit humor

Distilling moisture never deserts the night

An appeal for truth and natural observation

Ipsa dies alios alio dedit ordine luna[191]
Felices operum. Quintam fuge...

For various labors each revolving moon
Gives happy days, the fifth be sure to shun

Is this what, as a recent translator of Virgil calls in his introduction, "an appeal to truth and nature throughout all ages of mankind?" Must vain and idle superstition be thought truth and natural only because it is *old*? We know it to be false and consequently against nature: I am sure it shows that the foundation of the *Georgic* is false.

[191] Black-acre is first sown on the right day of the moon, and then is continued to be sown until, in its turn, white-acre is sown on the worst day of the moon. Now, what reason could Virgil give? Why should white-acre on the worst day prosper more than black-acre on the best day? I can only guess that his word. But it is remarkable that no other oracle but Virgil could have obtained a place for anything so unscientific as this (as the days of the moon) to stand among the transactions of that illustrious society whose motto is *Nullus in Verba*. [Unfortunately, the same unscientific method (of planting by moons and stars) persists so many hundreds of years later in great popularity among those people who aim to practice scientific agriculture. The practice of sacrificing to Demeter, of burning fields for fertility and many other Virgilian practices also persist, with, instead of ancient Priests, modern corporations certifying correct practices. It is a dangerous custom, made more so by a changing climate —A.B. & M.C.].

Virgil's one truth

It is remarkable that there can be found one useful truth in all the pages of the *Georgic* (the number of falsehoods and errors being too great to innumerate makes this exception all the more remarkable). Seeking for this one Truth in Virgil exemplifies the search for Truth in nature: the natural habit of truth is a plain dress, yet she is not easily found (being the daughter of time).[192] Unlike seeking Truth in nature, in seeking this Truth in Virgil, the moderns have no more advantage than the ancients: it is hard to find among all the lies.

Hic segetes, illic veniunt felicius Vvae

The harvest here, there vines more happy found

Vines will grow as well, if not better, in strong land. But light land is more easily hoed. Vines will grow wherever corn will grow (if there is sufficient heat to ripen the grapes) and corn will grow wherever vines will.

Virgil is impertinent

Nonne vides, croceos ut Tmolus odores,
India mittit ebur...

Do you not see how Tmolus his perfumes
Her ivory India, soft Sabaans gums
How Pontus heady Castor sends from far
The Spaniards' steel

Should any author but Virgil have given a caution to the Italian farmers against planting their lands with perfumes, ivory, frankincense, castor or steel, he would be thought very impertinent.

Jethro Tull's Supplement

Answering the objections of Equivocus in defense of Virgil

Equivocus exclaims against me horribly for the title of this Chapter, but without any reason: he is not content with the word "finely," but adds "judiciously," as if bad husbandry could be judiciously expressed.

I defy him to show any place in my book, where I have said an injurious word against the poetry of Virgil, or where he finds that I have said "that there is not a good line in all Virgil's works that relates to husbandry," or that Virgil's works "are fit for nothing but to be laid on a hand-barrow and thrown into the fire." These lies he has had the face to affirm in his dedication to my Lord

[192] It requires time and effort to find Truth. –A.B. & M.C.

Lonsdale. Yet I am sure I never said or thought there was one bad line in all Virgil's works; but rather I believe the praise due to the prince of poets is in respect of his poetry only.

Tillage is best done early and often

...Terrae
Pingue solum primis extemplo a mensibus anni
Fortes invertant tauri: glebasque jacentes
Pulverulenta coquat matures solibus aestas.
...officiant laetis ne frugibus herbae;

...Straight let the vig'rous steer
Turn the rich furrow in the new-born year,
And summer's heat with rip'ning suns pursue
The sluggish glebe, and all the clod subdue.
...lest the weeds the smiling blade withstand;

This is good husbandry, which I must maintain against Equivocus, who in his directions to his reading farmers tells them in his Preface to September, that it is time enough to break up strong land in Britain in May or in June, whereas Virgil directs it to be done in January or February. And what we esteem strong land in Britain is much stronger than the Italian, and our climate is more subject to rains, so our land should certainly not be broken any up later than theirs.

Our most experienced farmers find it a less expense, and infinitely more profitable, to break up their wheat-land in winter (being the same time that Virgil calls the spring); they say that this first plowing and a second in summer costs them less than one first plowing (or breaking up) in summer when the weather is dry. By the former method, they never fail of a sufficient pulverization to kill the weeds; but in the latter, it is as uncertain as the weather, which often disappoints them. Yet the weather in winter never does.

The consequence of this early fallowing is to require more iterations (or stirrings) than there is time to perform properly on land broke up in the summer, but this is the chief benefit of early fallowing: it is so found by all who practice it, as many do of late, plowing five or six, and some seven times, instead of one or two, on light land and sandy land. But Equivocus says, in Advertisement to his second volume, that it is the custom to plow once, some twice, and others three times at the most, in the stiffest land.

All farmers of my acquaintance that are eminent for being good husbandmen, and have practiced from their youth to old age, declare they are very certain they have many times been at a great loss by plowing their land too seldom but never lost by plowing any sort of land too often. This is from long experience; and I take it, is what Virgil means for strong land and is undoubtedly good husbandry, which nobody contradicts, except Equivocus, as above.

If the effect of pulverization were generally known (as it may be demonstrated) to procure and enlarge the pasture of plants, instead of only killing weeds, which is only accidentally done by pulverization, it could not be denied that pulverization is at least as necessary (and in a greater degree) to poor light land, as it is to strong and rich.

And it is, in fact, the custom in the South of France to plow up their light land in the winter, pulverizing it by frequent iterations in the summer; this is done in Languedoc on land so light that I have seen it plowed (for wheat) by a plow drawn by a single ass.

The Equivocal Society having ransacked their old heathen authors to find other reasons against tillage pretend pulverization to be one; it is indeed an effect of good tillage, but is no more a reason for it than changing the under and upper sides of the furrow is the reason for turning it. Equivocus says pulverization is poison to light land. What they say of the advantages of summer fallowing being another reason for tillage is no better, since such fallowing is only good tillage, not a reason for tillage. I do not perceive that they offer any other reasons; if they had any they would have produced them in contradiction to what I have said in my Essay.

Equivocus is against pulverizing this land, because he thinks it would make it too hollow. But in truth, the contrary of his opinion is true because pulverization makes its natural pores less and its specific gravity greater. And this Equivocus might have learned from Virgil himself, if his malice would have given him leave to inquire; for Virgil, in his second Georgic, relates an experiment which fully contradicts this his own precept: for dig a pit or hole in light land, and the same earth which comes out of it will not fill it up again. Its filling less room (by the breaking) is a proof of its specific gravity being increased.

He says, in page 13 of his Advertisement to his second volume, "If the soil was naturally light and hollow, over much ploughing, or pulverizing of it, would be not only needless, but also destructive to it."

In this Equivocus is right: too much plowing or pulverizing is impossible, unless where it is feared the soil should become too rich for the sort of vegetable therein to be sown.[193]

It is insufficient tillage only that makes light land become more hollow and light upon two accounts: first, as it does not sufficiently diminish the size of its natural pores, the largeness of which is the cause of its hollowness and lightness, for the size of none of these can be diminished but by breaking their partitions, few of which are broken by insufficient (Virgilian) tillage. Secondly, it becomes lighter on account of the size of its artificial pores, which, by insufficient tillage, are made large in proportion to the degree of insufficiency, but on the contrary, sufficient tillage makes the artificial pores very small and diminishes the size of the natural pores, in proportion to the degree of that smallness of the artificial.

[193] While Tull attempts mockery, it is unfortunately true that some people fear rich soil. On land we rented for potatoes, our landlord became concerned the soil was becoming too rich; this mysterious attitude was also found in a different landlord who we had rented land for salad greens. The soil had begun in the first case sandy and dry, and in the second so hard we had bent a pickaxe in the breaking of it. At the moment of their concern, it was like that soil which is sold for potting: soft, black as roasted coffee and rich; it would not get too wet or dry, nor too hot or cold; it was perfected by our work and envied by the neighbors. Yet was only by assuring our landlords that we would bring the soil back to the state we had found it in before we improved it that we were allowed to continue our work. This proved easy enough in the first case by practicing standard methods, the second case we had no opportunity to damage the soil because we caught the landlord stealing our tools and found occasion to terminate our rental agreement. –A.B. & M.C.

Tillage destroys weeds, does not promote them; all soil deficiencies may be cured by good tillage practices

Equivocus says, that in the west "they never plough their wheat-lands in the summer, nor till they are ready to sow them, well knowing that if they were to summer-fallow them, it would cause the ground to produce nothing but charlock, and several other weeds of that kind, which are all of them the indelible criteria of poverty."

But in truth these weeds are only criteria of the worst sort of Virgilian husbandry; for they grow much stronger and larger in rich land. But, when earlier and oftener plowed, the charlock seeds, etc. that grow are killed without stocking the ground with their species as they do in poor land that is plowed late and only once or twice (where all or most weeds that grow are sure to live and propagate).

I remember to have formerly seen my chalky hill look all over yellow with blossomed charlock when in the hands of a Virgilian tenant, but since they have been a few years used in my hoeing tillage, very little charlock appears in them, nor is there any more charlock on my hill whose second stratum is clay, which about twelve years ago had the thickest and largest crop of it that ever I saw: the seed was ripe, and stood all winter, and was shed on the land to fill it fuller. Yet a few years of my potato and turnip management totally extirpated the race of charlock from there also.

Charlcok, therefore, is neither spontaneously (which Virgilians term naturally) produced, nor is it an indelible criterion of poverty; for this hill, since it has been made dry, appears by the crops of all sorts it produces to be the richest field I have.

Charlcok and other weeds may be a cause of poverty, but never can be an effect of it, in any soil whatever.[194]

[194] Some agronomists today will look at the weeds growing on a field to diagnose why the crops are not succeeding, presuming that certain weeds prefer a particular kind of mineral, or that a lack of certain minerals would lead to a particular kind of weed. The idea the weeds would eat a kind of soil unsuited for domestic plants throws back to the idea that different plants eat different foods, and what begins with an understanding that certain plants require slightly different compositions of food results in an ignorance of the reason why the weeds are able to obtain their food better than the domesticated plants: weeds – and many wild creatures – are better foragers out of necessity, and this only justifies the better feeding of domestic plants.

The agricultural consulting company, Sustainable Idaho, says in their publication *What Weeds Are Telling Us* (http:// www.sgidaho.com/What_Weeds_are_Telling_Us.doc, last accessed 2009), *"by recognizing the species of weed growing, you can also diagnose the deficiency. Since most weeds have the job of healing soils to bring them back into balance, they respond to where they are needed most. Here are a few examples of which weeds say what:*

- *Dandelion: calcium & iron deficiency, high potassium, and low organic matter.*
- *Mullen: calcium & vitamin C deficiency, high salt content and magnesium.*
- *Nightshade: calcium, phosphorus& copper deficiency, high potassium*
- *Lambsquarter: calcium & phosphorus deficiency, high potassium @ magnesium*

These are just a few examples. Notice a common theme? Low calcium. This could mean you need to add calcium, but it often means the calcium is there but isn't accessible to the plant. If you were to take a soil test [in this area] it would likely point to high alkalinity in the soil as being the culprit. However, trying to adjust alkaline-acid

Equivocus is wrong to infer that this western husbandry is not Virgilian, because he thinks the farmers there never so much as heard of Virgil's Georgics, when the praised commentator proves it to be so from the Latin words used among husbandmen of that country in their rustic affairs.

Equivocus, in his last-quoted page, and in his two next following it, pretends to bring this opinion of mine concerning pulverization to the test by what he most childishly calls an experiment, which is only this, that there is a sort of hollow light land about Wilcot (a place I do not know) in the county of Wilts, part thereof being well limed, that produces much better than adjoining lands, of the same sort, not limed. And from hence infers that pulverization is a poison in some soils.

But whether this argument be a test of my opinion, or rather a test of Equivocus's understanding, I leave to the determination of a sober reader.

This test which Equivocus proposes, could prove nothing to the purpose, but if anyone will be so curious as to see a test of it, he may go to Fiddleton, and several adjacent parishes not far from Wilcot, and within eight or ten miles of the Devizes in Wiltshire, and he will be convinced (by the present practice there) of the benefit of pulverizing light land: he will see thousands of acres that were time out of mind, until within these last twenty years, kept in the once plowing husbandry, now vastly improved by pulverization with frequent plowings. They have there proved by practice what I have demonstrated in theory, that light land requires more plowing than strong land: they say also, that the summer sun and summer plowings are of greatest benefit to light land; they further say that the longer it is kept in that pulverizing way, the more fruitful it grows.

These lands were formerly sown (alternately) every other year upon once plowing, as the rest of the neighborhood still are, but now these are sown three years successively on frequent plowings, and are of double the value to what they were formerly, and to what the other adjoining lands of the same nature unpulverised in the Virgilian method are.

Five years, whereof the three first are sown and the other two unsown, are called a round; and they find that every successive round the land grows better and less light, which proves that the Anti-Virgilian pulverization in time destroys, or, at least, abates, that pernicious leaven (which was the cause of the hollowness or lightness), and increases the cement of the soil, as the superficies of its parts are frequently increased.

balance through chemical means such as sulfur or other acidic amendments further imbalances the soil, leading to other more complicated problems

Here is where biology and chemistry meet. By adding organic matter in the form of compost, you can naturally neutralize a pH imbalance whether your soil be too acid or to alkaline. Also the addition of well-made compost helps to add much need microorganisms to the soil, including a healthy dose of fungi. Fungi are the key to unlocking calcium in your soil as they dine on the unavailable forms and excrete it in forms recognizable to your plant."

It occurs to us that the cost of compost could be avoided and microorganisms encouraged through Tullian hoeing, and that the Calcium would be more readily accessible in a soil that is better pulverized. Bill Duesing reports in *The Calcium Cycle* for the Yale-New Haven Teachers Institute in 2009 that all the Calcium in the sea has been cycled to the land and back into the sea: the problem is not in adding more Calcium to the soil, but using what calcium is available, capturing more of that which comes from rain and dew and allowing microorganisms to balance the amount of Calcium in the soil through their metabolic processes.

It is important to remember that all the minerals a plant requires can come from the ocean and the actions of microorganisms, and that these minerals deposit very quickly with the help of good hoeing.–A.B. & M.C.

Though the staple of this land may be too thin to acquire the name of strong land, it loses so much of its lightness that it subsides sufficiently after sowing, but not too much.

In Gloucestershire also, which is a western county, I am well informed that great quantities of very light land, which when kept in the *sat erit* husbandry of Virgil, were let for half a crown[195] an acre, but being now brought into the pulverizing method, are let for ten shillings and acre.

But there is a misfortune in many parishes, that the custom does not permit any one to pulverize his light land by tillage until an enclosure be made of them.

Full experiments of this doctrine have been made in Hampshire too, and in other places, which show the bad theory and practice of Virgilians.

Experimental results are ignored out of stubbornness

And to confute the *sat erit* maxim of Virgil, even the practice of the parish where I live is sufficient. The greatest part of the south side of it is light land, formerly downs, and on the north side, is poor, sandy, light land, formerly a heath: in this they always sowed their wheat on once plowing, until within these last 20 years. It was about 17 years ago that I was walking with a farmer in this part and saw on one side of a hedge a little field in the occupation of a gentleman who had fallowed it early, and plowed it three or four times afterwards, and sowed it with wheat without dung: on the other side of the hedge was a field sown with wheat on once plowing, according to the old custom, well dunged: it was then near harvest, and the farmer judged the crop of the Anti-Virgilian field at four quarters[196] to an acre, and the other at two bushels, or three at the most; and I afterwards found that he was right in his valuation of those different crops. He said the field which had the poor crop was always accounted the better land of the two, though of the same sort. He said too, that his late father used to observe that this custom of once plowing did never produce so good crops as the same sort of land did in places where it was the custom to plow often; and the farmer himself could remember fifty years and never found their once plowing succeed well. I then asked him the reason why the continued such a bad custom, which was never known to succeed. His answer was, "we are still in hopes."

But that custom is now so entirely worn out, that I do not believe there has been an acre of wheat sown upon once plowing these ten last years in this parish, which is a large one, lying in two counties.

The south side of the parish being very high down-land was reckoned too poor and too light for wheat.

They thought with the Virgilians, that much plowing would make it yet lighter; therefore they used generally to sow it with oats on once plowing, and to let it lie unsown more years than sown. But now they are convinced of that error, and till the same land as much or more, than their strong land, of which the middle of the parish that lies in a bottom consists (though it is not my fortune to have any of it). And that light land is, within these last twenty years, so much improved by good summer tillage that it produces rather better crops of wheat and barley than their rich low land does; it is not, therefore, become lighter or poorer by pulverization, but more dense and richer.

The Virgilian error in this matter seems to be their mistaking exhaustion for pulverization, for when they sow upon two or three plowings, which are insufficient for light land (especially

[195] A half crown is 2 shillings and 6 pence. –A.B. & M.C.

[196] A quarter is 8 bushels, 4 quarters is 32 bushels. –A.B. & M.C.

whilst full of weeds), the exhaustion may be greater than in proportion to such pulverization, and then the land must become poorer. This effect, which is owing to exhaustion only, they falsely impute to pulverization, for it is demonstratable, both in theory and practice, that no land can become poorer unless the exhaustion exceeds the pulverization of it, nor richer, unless the pulverization exceeds the exhaustion.

When a well-tilled field is to be sown with corn for three years, leave the land in the middle of it unsown, pulverizing it by the plow very often, and suffering no vegetable to grow in it for the first and second years; but the third year let the whole field be sown alike. Then if this third crop be poorer than the crop of the pulverized land in the middle of it (as it certainly will), it will be evident that the poverty proceeds from the exhaustion, and not from the pulverization.

It is also demonstratable, that light land requires a greater degree of pulverization than strong land, when the exhaustion of both is equal.

Tillage is a catholicon

In answer to the ridicule of Equivocus, in page 15 of the Advertisement to his second volume, about pulverization being no catholicon, I say, it may be proved so far a catholicon, that it enlarges and enriches the vegetable pasture, and (if made by the plow) kills weeds, and diminishes the too great specific gravity of strong land. It retains competent moisture, but not too much water. If in proper ridges, it lessens the labor of cattle by causing the plough to go more easily in strong land.

If Virgil gives no other reason for tillage but the killing of weeds (as I think he does not), and yet in his *sat erit* directs the plowing of poor land in such a manner that weeds cannot be killed, but rather propagated and strengthened by it, how can there be a worse theory than Virgil's? And would it not be wonderful, if the Equivocal Society were what they pretend to be, that they should not give some reasons why pulverization kills weeds in strong land, and breeds them in light land, as they assert it does? But that assertion is so far from being true that pulverization by the plow more easily kills an equal number of the same species of weeds in light land than in strong, because, the former being more friable, the imprisoned seeds are sooner set at liberty to grow in it, in order for their destruction. Some sorts of dung increase weeds, no sort of dung or manure kills them; yet the Virgilian, in light land, wherein the weeds are most abound, uses much dung and very little plowing.

...Sterilem exiguous ne deserat humor arenam.

...Lest moisture desert the barren sand.

However this reason may hold in other countries, it is certainly wrong in England: for all experience proves, that the more such dry light land is pulverized by early and frequent plowings, and the deeper the same is pulverized soil is, the better the corn that grows on it will endure a dry summer.

By experience, I do not mean the experience of these Virgilians, who know not what pulverization is, believing that twice or at most three plowings is the utmost that tillage can do, the notion of infinite or indefinite division being to them unintelligible and ridiculous.

Sat erit a great mistake

I have been informed, by a hill-country farmer who had learning enough to so far balance the common prejudices of his Virgilian education that he managed for many years part of his dry, light, down land in the same manner that common good husbands manage their strong land by plowing it three or four times, singly maturing it with the fold, and sowing only one bushel and a half of wheat seed per acre. The other part of the same land managed in the old Virgilian method: he plowed once, manured more, and sowed four bushels of wheat per acre. This greater quantity of dung and seed were much more expensive, but the true measure of difference in these two managements was that every dry summer the Virgilian produced miserable poor crops (which were too big and lodged).

Not to bring in questions of whether the lodging might not have been prevented by yet more lightly folding, it is by this experiment made very plain that the more this dry, light land is pulverized, the more moisture it retains in summer. This farmer is yet living, a man of credit, and can easily make appear the truth of these facts; and I have myself always observed the same effect of pulverization in regard to moisture on all sorts of land with which I have been acquainted, at what times so ever they were sown or planted.

And this moisture obtained, or rather retained, by pulverization, whether from dews or rains, is never injurious! For, as pulverized soil holds a small quantity of water longer than the *sat erit* tillage does, so it suffers water, when in too great quantity, to descend or exhale sooner from it[197]. The lodging of the above-mentioned crops on that very dry land must not be imputed to too much water, but rather to too great a number of plants or other causes.

He directs that poor land should be plowed late, for fear the moisture should be dried out of it. Yet this kind of land has more need of being enriched by early and frequent plowings, for all its moisture will be exhaled, and, for want of being opened, can receive little return from the atmosphere. The later it is plowed, the drier it will be.

The *sat erit*, is therefore a great mistake.

But it is only the mistake of Virgilians, and of such vulgar who (as Equivocus, in page 2 of April, says of the lower class of readers) "are not able to distinguish truth from error, or right from wrong." It is these only who cry, "it is enough!" when their land is ploughed twice, though it has thereby attained no competent degree of pulverization, but such as serves only to set some of the weeds growing, which when ripe, shed their seed to be afterwards plowed into the soil so that they later compose a considerable part of the staple of their lands and come up thick. They fancy the same species are produced equivocally without real corporal seeds and then they say, it is plowing that breeds weeds, which is because they plough often enough to make some of the seeds (of which the soil is very full) grow, but not often enough to kill them when sprouted. If the lands of England were all in such vulgar hands, those three syllables *sat erit* would be, I suppose, a loss of three million Sterling yearly to the public.

It seems absurd to be so solicitous for laying dung upon the land to which pulverization is thought to be poison, when the effect of all sorts of dung is to pulverize more or less in proportion to the quantity of salts they contain.

That pulverization is an effect of those salts is so evident from the demonstration of every experiment that I believe nobody ever did deny it; but whether dung has any other considerable

[197] This is due to changes in soil structure, increased microorganism activity and changes to soil composition. –A.B. & M.C.

effects upon a soil is uncertain, for the warmth occasioned by their ferment cannot be much, and the addition made to the staple by the substance of the usual quantity of dung of any sort is very little when reduced to earth.

The truth of it is, such poor light land requires a considerable quantity both of dung and of tillage to pulverize it in proportion to the degree of its poverty. The Virgilians judging otherwise leave out the tillage, and add more dung than is usual in any other species of husbandry, and the consequence of this practice is that much of the greatest part of this land must lie still at the value of about 2s. per acre, for keeping of a vast number mostly of dry sheep for doubly dunging of the small remainder, which also must not be often sowed, and produces commonly very light crops. But, as I am informed, when farmers of a religion (or education?) different from those bigoted Virgilians that come among them, they leave out part of the dung, and add more tillage, sow less seed, and, by a competent use of each, raise better and more crops, making a great improvement on those lands, which, by the Virgilian husbandry, are of little value.

None of the improvements made on any sort of arable land by foreign grasses or turnips could have been introduced into Britain without renouncing the *sat erit* doctrine of Virgil, for they will not succeed on any sort of land without pulverization by tillage. and they are most generally made on light land, and, therefore, may be properly called Anti-Virgilian. And so may most sorts of hoeing culture for corn, which are always found very beneficial to the husbandman who uses them with discretion.

Clover does not improve soil by killing weeds, the tillage required for its planting does

Clover does not improve the soil by killing weeds as the vulgar imagine; for, in truth, weeds, especially natural grass, will kill or spoil the clover. The improvement is therefore from other causes, the chief of which is the preparing the land for it by tillage, which kills the natural grass and most other weeds (and those that are left are hindered from propagating by seed if the clover is mowed before they are ripe, and by the rotting of its large roots, and by such other benefits as are shown that a soil receives from sanfoin, and other long tap-rooted plants).

The benefit that the clover and turnip husbandry brings to a soil consists in the pulverization it occasions by tillage as well as by fermentation.

Burning land is certainly a bad idea, and was, in fact, directed by Virgil

Against burning such land Equivocus agrees with me, but says that is not the land Virgil names. To which I answer that the meaning of Virgil in this point is best known by the followers of his husbandry, and if his late commentator is in the right as to the southern parts of England being the chief seat of it, "where Latin words are in use at this time among the rustics," which I believe is true, than there can be no doubt of Virgil's meaning, or that I have perverted it for it is, and always has been, the practice of those Virgilians to burn the surface of their poor, thin, hollow downs, and this is the only burning I have treated of. Nor did I hear that any other sort was burnt till of late, and believe burning the other sorts, which Equivocus mentions, is a new practice, and now here common.

Equivocus pretends that Virgil does not mean the burning of this light sort of soil because he has just dispatched it before by his *sat erit*. But this pretence is without reason, it being the practice to sow such sometimes without burning, and indeed oftener than with it and Virgil seems here to

treat of burning the same sort of poor land, the plowing of which he had just before treated of in the *sat erit*.

He pretends, that Virgil meant those kinds of soils that owe their "sterility to the too close contexture of parts, which will not suffer the superfluous water to pass off, or the roots of corn or trees to penetrate or find their way into, or pass though them, until they are subdued by fire."

But how burning should prevent the too great plenty of water from causing barrenness by standing too near the surface I cannot imagine, for barren clays, and that tenacious kind of land, are generally more tenacious below the staple than at the surface, which is, I suppose, the only part to be burnt. And the fire diminishing that, the next surface that remains after the burning will be lower than the former, and thereby retain more water in and upon the remaining staple.

There may be, and I am informed there is, a sort of deep land covered with coarse grass, sedge, and trumpery, which burning might make a quick dispatch of and, by reason of its thickness, enough may be left for many burnings. But as the upper part is always the richest, some of which the fire carries away and the rest it converts into a manure, the staple must be diminished, and by many repetitions at last be much impoverished. Every burning makes it thinner, though it may be a long time before such a soil becomes too thin by frequent burnings.

Equivocus's experiment of burnt earth put into a pot, and set out for a year, increasing its weight a sixth part, proves nothing, but that wet earth is heavier than dry earth. It is such another experiment as he gives elsewhere, of old pieces of bricks being thrown out by accident, and in some time increasing in their weight. How knows he their weight was augmented, if they were thrown out by accident without weighing whilst dry?

Such precarious experiments are convincing to no philosopher but Equivocus.

Equivocus says, "that if Virgil should be wrong, it is certainly no great fault in a poet, since authors in prose are sometimes guilty of worse."

I do not say it is a great fault in Virgil to be wrong either as a poet or a husbandman; I only think I prove that he is wrong in the latter capacity. And I have not so much veneration for the authority of the prince of poets, as to think that right which my reason and experience convince me is wrong, and I cannot help thinking the late commentator much in the right, when blaming Mr. Dryden's version: he says, that if you take from Virgil his figures, you take the club from Hercules. Neither can I dissent from Seneca in my opinion of the Georgics, because he, living nearer to Virgil's time, could better judge of the truth of them than Equivocus. Take Seneca's words in his 86th Epistle, Englished by Mr. Cowley in the notes on his Davidies: "Virgil did look not upon what might be spoken most truly, but what most gracefully; and aimed more at delighting his readers, than at instructing husbandmen."

Hence, I think, that one who writes on the same subject, with a quite contrary view, (as I have done), his husbandry may, in that respect, be termed without arrogance Anti-Virgilian.

Dews add considerable water to the soil

Humida solstitia atque hyemes orate serenas
Agricolae...

The solstice moist, serene the winter sky,
For this, ye swains, entreat the powers on high.

Here Equivocus makes heavy clamor against me for advising to keep land moist by retaining the dews: he says, that some nights let fall no dews, but such nights are certainly very rare, and when they happen, there is the more need to preserve those dews that have fallen in the moist nights.

He says, that if I had the power of correcting the Liturgy, I would expunge the prayer for rain: but Equivocus, no doubt, means no other liturgy than that of Virgil to his god Augustus. See his Pref. to Sept.

Ignarosque viae—miseratus Agrestis
Ingredere, et votes jam nunc assuesce vocari.

Pity the rustic for not knowing the way to begin
Against the obstacles he comes upon daily [198]

Virgil might have advised them to remedy, in some measure, the inconvenience of dry weather, by frequently hoeing the soil to open it, for the reception of the dews which moisten it and refrigerate the roots in the night, after the scorching heats of the day since he knew that

Noctes lentus non deficit humor.

Distilling moisture ne'er deserts the night.

He might have advised to plant the corn in such a manner that it might be protected from the injuries of cold winds and water, as in the chapter "Of Wheat" is described

Ipsa dies alios alio dedit ordine Luna
Felices operum. Quintam fuge, &c.

For various labors each revolving Moon
Gives happy days; the fifth be sure to shun.

Equivocus falsely accuses Tull of disrespect, and not finding one useful Truth in the Georgic: by quoting falsely, Equivocus does not prove his case

In my remark on the fancy of the moon, Equivocus accuses me of using "all the opprobrious language I am able to bestow on Virgil (and his commentator)" but this is so false that I defy him to show any opprobrious language in my Essay.

It is also as false for him to assert that I say, there is not "one useful truth discovered in the Georgic."

The trick of Equivocus is to quote falsely, as he does very frequently, if not generally: he leaves out the word new, which quite changes the sense of my expression.

But although it should have been said, that Virgil had been the discover of no truth in his Georgic the assertion had not been amiss; because he who writes of no truths but what he takes from books written a thousand years before him cannot be a discoverer of it.

[198] Translation by Aaron Brachfeld

Equivocus excuses Virgil concerning the influence of the moon, as follows, "an error (if it may be called one) of which not only Virgil, (who is chiefly celebrated for his poetry), but also the ancient husbandmen, who wrote before and after him, were guilty; and was in all probability inserted by Virgil in compliance with the currency of the times, rather than out of any serious belief of its influence on planting or sowing."

This is a wonderful vindication of the veracity and sincerity of Virgil, for which the Virgilians are much obliged to his champion Equivocus, who is such a zealot of truth, if you will believe him. But it is plain that Equivocus pretends to have more faith in this error, than he says Virgil had, and patience for a man of common sense to read. Also in his Essays some works are directed to be done in the increase, and others in the decrease of the moon.

Yet, in his Essay of June, page 99, he says, "but whether the increase or decrease of the moon affects, it seems at present to be an antiquated as well as useless speculation."

Is this (the above quotation from Virgil) what the late commentator in his Preface calls, "An Appeal to Truth and Nature throughout all Ages of Mankind?" Must vain and idle superstition be thought true and natural, because it is old, though we know it to be false, and consequently against Nature? I am sure it is far from showing, that the foundation of the whole Georgic is truth; unless he left out this, and most of all the rest. For indeed I cannot find one new useful truth discovered in all the pages of the Georgic, though he says, every page affords instances of such; therefore I agree with that commentator, that it is endless to enumerate instances of that kind; because I hold, that nothing cannot be numbered.

Hic segetes, illic veniunt felicius uvae.

The harvest here, there vines more happy found.

Vines will grow as well, and better in strong land, but light land is more easily hoed. Vines will grow wherever corn will grow, if there be sufficient heat to ripen the grapes. And corn will grow wherever vines will.

Nonne vides, croceos ut Tmolus odores,
India mittit ebur...

Do you not see how Tmolus his perfumes,
Her iv'ry India, soft Sabaen's gums,
How Pontus heady castor sends from far,
The Spaniard's steel...

Should any author in prose have given a caution to the Italian farmers against planting their lands with perfumes, ivory, frankincense, castor, or stele, would he not be thought very impertinent?

Cultusque habitusque locorum[199] is that fond maxim that forbids all new improvements. This verse seems to forbid improvements by exotics, and if it had been always observed, we should have had neither apples even in Herefordshire, nor cherries in Kent.

[199] "Maintain and hold what is here" Translation by Aaron Brachfeld

Equivocus, though he explains against me in a scurrilous manner for disapproving, he excuses Virgil again by a poetic license in page 30, of the Preface to August, "and what fool could not have said as much as he has done? For had Virgil been serious, and wrote in prose, he might have been deemed as mad as several people do this author (i.e. the horse-hoer); but poets sure have a little more liberty to make use of flights in verse than those who write in prose have."

Equivocus wrong in suggesting that Tull could not understand Virgil's Latin

Now, I suppose, that every impartial reader will allow, that Equivocus himself has implicitly acquitted me of "either not having understood Virgil's meaning, or else willfully misrepresented it." For if Virgil was neither sincere, nor serious, nor believed himself what he wrote, as his champion Equivocus urges in defense of Virgilian husbandry, how shall anybody understand his meaning? Or if nobody but Equivocus understands it, how can any other willfully misrepresent it? Or how should I, who am no critic, be certain of a poet's meaning, which the critics among themselves differ about? Our critic Equivocus, against the opinion of all others, will have it, that where Virgil says, *Hoc imitamur arando, by putre solum*, Virgil means, *putridum solum*, but it is certainly absurd to conclude, with Equivocus, that the design of tillage is to imitate putrid, cold, water land. He has also made bold to correct Dr. Trap's translation of *male pinguis Arenae*; changing barren sands to mouldered clods.

Virgil says, *putres-sulci* is the soil whereon to sow alfalfa, and it is well known, that even in hot countries, that grass will not succeed on a water staple: therefore his *putre solum* is not *putridum solum*, but rather *molle*, or *mite solum*, a loose, mellow soil.

For my part, I have taken Virgil's meaning in the true sense, to the best of my own judgment. And do not think it worthwhile to enter into any dispute about it unless it were of greater importance than I apprehend it to be. So I leave Equivocus to expound upon it by a poetic license, the latitude of which I am not poet enough to determine the extent of.

Was Virgil simply taking poetic license? Treat the Georgic as an excellent work of poetry (which it is) instead of a farming lesson (which it is not)

But if Equivocus thinks to take refuge himself in poetic license as felons are entitled to the benefit of the clergy, he should have wrote in verse to entitle himself the benefit of the poets. But then he must have taken care to write like a poet, as the felon must read like a clergyman.

In page 32 of the same Preface, he demands the reason why I find fault with one of the best authors of antiquity, whose husbandry has stood the test of so many ages? To which he gives himself an answer as ridiculous as false. And then he goes on to say of me as follows, "he might, indeed, have attacked a Bradley, or even a Woodward (as he has done) with very good success, but a Virgil is certainly an over-match for him and it is much to be wondered at, that Virgil's translator, who has so just a value for him, should let this great adept pass so long unobserved."

It is well known, that Virgil was bred a Ferrier, which we call a horse-doctor, which trade has generally in most countries annex to it that of a blacksmith: it doth not indeed appear that he had both those trades, but however, his Ferrier's trade was sufficient to take up his time in learning and practicing it until he went to Rome, and then he had something else to do than plow. Therefore, the only time he was likely to have for plowing must be before he was arrived at years proper for learning his trade, and most of that time, too, seems to have been spent in keeping goats or sheep, as

many of the boys of our lower class of people do. However such an age, wherein even plow-boys that do nothing else but plow, are not suited for making useful observations upon arable industry. Virgil could have little or no experience in it of his own, and must have taken what he wrote from books written by those authors who lived when agriculture was in its most imperfect state, as Hesiod, and the other Greeks did.

Virgil was born a poet, and undoubtedly the best [of the Latins] that ever wrote; but I believe he was not born a farmer: talents in husbandry must be acquired by long experience and diligent observations thereon and he that will make any improvements therein must sometimes deviate from the old beaten road by way of trial.

By asserting that Virgil's husbandry has stood the test of so many ages (1,700 years), Equivocus contradicts the commentator he praises, who with great truth affirms, "there is more of Virgil's husbandry put in practice in England at this instant, than in Italy itself." Which is as much as to say, it has not stood the test even in Virgil's own country, but is there disused. And, I believe, if that matter were fully inquired into, it would appear, that it never was much practiced or approved of about Rome or any other part of Italy.

From the Agrarian laws also, the same may be inferred; for that small portion of land allotted to each family, in this Virgilian culture, would not have been sufficient to keep those families from starving.

I did personally observe agriculture in Italy and saw that Virgilian methods are being abandoned

And in my travelling through that country (I went the whole length of it by land), traversing the Kingdom of Naples almost all over, I made a considerable stay in many places there. And in about two years' time, I never could find or be informed of paring or burning, or of raftering[200], or of sowing corn without many plowings there, and yet their land is not strong.

And, I think, it looks very odd, that Equivocus, after he has affirmed that the husbandry of England has been for these 1,700 years Virgilian, should, in page 2 of his Advertisement to his Vol. II., talk of "rousing our countrymen, if possible, out of that fatal lethargy into which they have long fallen." What test is likely to have been made in such a country, if Equivocus speaks truth? Or if the Virgilian husbandry they had so long practiced in their lethargy were right, why does Equivocus endeavor so obstreperously to rouse them out of it? But he seems to condemn the English Virgilian husbandry yet more in page 4 of his preface to July, when he affirms, that "wildered in dark uncertain paths, not having come into the true nations in practice and theory till of late."

Burning the surface, and plowing light land late, and but once or twice, and sometimes half plowing it, make that scheme of husbandry that Virgil's translator justly imputes to him and whom he would not wrong actually very bad. He is warranted by the general practice of the southern parts of England, where the worst sort of Virgilian husbandry reigns, being in most other places abandoned by reason of experience (except by those who adhere more to blind custom than to reason and must by necessity be abandoned), and in those southern parts also, were it not for their vast tracts of downs, which maintain such extraordinary flocks of sheep that suffice to help them, as I am informed, to dung their once plowed land twice over (which dung, with a great quantity of seed harrowed in among the high charlock and other weeds, produces them crops so uncertain that it is a

[200] Raftering is plowing one furrow, and leaving another unplowed, which is at most but half a plowing.

rule amongst the farmers there, that the profit of sheep must pay their rent). This warrant is not convincing, since I hear of more farmers that go bankrupt in that country than elsewhere.

And one thing I am sure they will readily grant me, that were all their downs taken away, they would either have to change their Virgilian husbandry on their arable land or desert that Virgilian country. For without sheep, their land, with their sort of single tillage, would not produce corn either to pay rent or to maintain them in food.

When Equivocus pretends to prove by experience that Virgil's bad husbandry is best, he has recourse only to the experience of Virgilians, which proves no more than that Virgil's husbandry is Virgilian and not that it is better than any one species of the Anti-Virgilian. Truly, every proper trial proves it to be worse.

Virgil's Georgic very pleasant, innocent, amusing, diverting poetry, captivating to reasoning minds. However, the Georgic was intended to praise a Roman government based on the perpetual slavery of the bravest people of the world, and Virgil himself was an enemy to liberty. In any case, he was one of the best of poets, and the worst of husbandmen

Poetry, like music, is a very pleasant and innocent amusement of life; but we ought not to suffer our diversion to captivate our reason and if we seriously consider the scope and design of the Aeneid and Georgic, what opinion can we have of Virgil's regard for truth? Or if it be true, as Ruaeus relates, that Virgil's advice and persuasions entailed perpetual slavery upon the bravest people in the world, we cannot but know what a patriot he was, and how his principals ought to be esteemed by all the lovers of liberty. And I do not think it any more injurious to Virgil's memory to say, that he was the best poet, and the worst field husbandman, than it is to Tull's to say that he was the best orator and the worst poet.

CHAPTER TEN: OF TURNIPS, RYEGRASS, ANIMAL PASTURE, GRAZING, FRUITS AND VEGETABLES

TURNIPS

Turnips only recently domesticated in England

As far as I can be informed, it is only recently that turnips have been introduced into English agriculture.

All lands, when made fine by tillage, will produce turnips, but not equally as well: turnips are thirsty plants that require heat: sandy and gravelly lands are the best, chalky grounds are the worst

All sorts of lands, when made fine by tillage or by manure and tillage, will produce turnips...but not equally as well. Chalky land is generally too dry (a turnip is a very thirsty plant). In dry, poor land turnips take too long to mature, and the fly is apt to destroy them before they are ready for harvest. However, I have known them to succeed on such land every once in a while.

Sand and gravel are the most proper soil for turnips because it is the most easily tilled, the warmth of the soil causes the turnips to grow faster (and so they are able to be harvested before the flies can get them), and such soil, when well tilled and horse hoed, never wants sufficient moisture—even in the driest weather, if the turnips are deep hoed and drilled.

If well tilled, dews provide enough moisture for germination

If deep hoed and drilled, turnips will come up without rain and prosper with only the moisture from the dews (which are admitted as deep as the pulverization reaches). If tillage is undertaken to a depth of more than 5 or 6 inches[201], the hottest sun will not bring the soil to exhale all the dews from the soil of England: I have known turnips to thrive in a dry summer due to repeated deep hoeing...both in sand, and in land which is neither sandy nor gravelly.

[201] We typically till and hoe no less than 6 inches deep, and attempt to till and hoe between 12 and 24 inches deep. 4 inches, when good tillage equipment or time is lacking, begins to be sufficient. 6-12 inches begins to be adequate. 12-24 inches begins to be good. In places dryer and hotter than England, the farmer must dig deeper. –A.B. & M.C.

Hand hoeing is insufficient, especially when hoers are deceitful

When I sowed the turnips by hand, and hoed them with a hand hoe, the expense was great and the operation was not even half performed due to the deceitfulness of the hoers (who left half the land unhoed, covering it with the earth from the part they did hoe to disguise their treachery and to help the grass and weeds grow faster). A large quantity of land cannot be managed quickly enough by hand.

When I drilled upon the level at three foot rows, a trial was made between those turnips and a neighbor's field. My neighbor sowed his turnips at the same time and his required hand-hoeing at a cost of 10 shillings per acre and, in the end, had not half the harvest of mine.

Plant turnips on ridges with one row per bed and with six feet between rows and yield should be double that of turnips planted three feet apart on the level – however, level-planting is better for dryer, hotter climates

I have found that turnips, planted on ridges with six feet between rows will make a crop double to those that are planted on the level (or even on ridges) with three feet between rows.

Plant on the Ridges

It is impossible to hoe-plow turnips as well when they are planted on the level as when they are planted upon ridges, for if we plow deep near to the row, the soil will come over on the left side of the plow and bury the young turnips. But when they stand on the ridges, the soil will fall down into the middle of the row.[202]

Plant turnips in halves: half four inches deep, and the other half one inch deep to guard against uncertain weather: if the weather is dry, the deeper ones will come up, if wet, the shallower ones will – planting polycultures with cold, hot, dry and wet adapted plants similarly reduces risks of a variable climate

To ensure that the turnips come up quickly, plant in every row half the seed at four inches deep and the other half at half an inch deep.[203] When the turnips are planted in this way, if the weather is dry, the deepest seeds will come up. If the weather is wet, the shallow will come up first!

[202] In dryer, hotter climates, it is better to plant on the level to reduce evaporation. –A.B. & M.C.

[203] Similarly, a polyculture guards against weather and other disaster: if a dry season crop fails, a wet season crop likely will succeed; planting cold and hot plants together is a good way to reduce a farmer's fears in variable climates. –A.B. & M.C.

Mix old and new seed at two different depths for four sprouting times: older seeds come up later than newer seeds. This reduces the risks of crop loss due to herbivores by allowing predators to respond to the herbivore population should it be abnormally large

If you plant half new seed and half old seed (mixing the old in with the new), the seeds will germinate four times: the new comes up a day quicker than the old, the shallow come up before the deep. These four sproutings will give the turnips an advantage when escaping the fly: those that came up the day after the fly attacked will not be destroyed.[204]

Covering the turnips with a little soil protects them against insect pests without significantly damaging them; replanting if destroyed also will result in a crop with little additional expense. Rolling the ridges compresses it and reduces the ability of insects to lay eggs in the ground, and while damaging to the crop, is remedied by hoeing the aisles

Another way to give the turnips an advantage over the fly is to hoe-plow them as soon as they are about to be attacked: burying them hides them from their enemies.

You may also drill a new row of turnips as soon as the old are attacked, without replowing the land.

Another method of escaping the fly that is more certain and infallible is to roll with a heavy roller the ridges after the turnips have been drilled. This closes up the cavities of the soil and prevents the fly from entering and exiting, from laying eggs or hatching eggs, or otherwise bringing forth young flies to prey upon the young, sweet turnips – turnips, before their secondary leaf has emerged, are very sweet. I have always found rolling to disappoint the fly, but very often it also disappoints the farmer who sows their crops at random in the field through broadcasting because the rolling makes the ground so hard that unless the turnips receive a deep hoeing, they will turn yellow, dwindle and grow to no perfection.[205]

Drilled turnips, planted in single rows with 72 inches between rows, may be rolled without danger: the ground can be hoed until it is not hard and the hand-hoe will easily weed around the turnips at a price of 6 pence per acre or less. The horse hoe can, in those wide aisles, plow at any time (wet or dry) and though the turnips might have been neglected until stunted, the deep hoeing will recover them to a flourishing condition.

When 72 inches are allowed between rows, aisles may be left higher than the beds

The 72 inches between rows of turnips may be left higher than for double-rowed crops because there is more soil the aisles (the single row takes up less space).

[204] Though the difference in sprouting is often more than a day, no matter how long the interval, from observation, it appears that this is because the predator population can have time to respond to abnormally large populations of potentially damaging herbivores either through migration to the food supply or through population growth. –A.B. & M.C.

[205] A truly infallible and certain method to prevent predation is to increase biodiversity and biodensity: the flies, deer, or whatever else might eat your crops are kept in check. –A.B. & M.C.

Weed and thin the turnips early.

Drilled turnips, being nowhere but where they were planted in rows, are more easily seen than those which come up at random and may therefore be sooner singled out by the hand-hoe...which is another advantage because the sooner they are set out, the better they thrive (the sooner they are made single the better. When they come up thickly, it is more difficult to make them single if they are neglected at their first coming into rough leaf. If they come up thinly, they may be left until the best convenience of singling them).

Plant thinly: 3-4 ounces of seed per acre are typically required. An exception is when raising sprouts or baby greens: planting densely retards growth, stunts them and otherwise makes a more desirable product that is easier to harvest

3-4 ounces of seed is the usual quantity needed to drill turnips, but 3-4 pounds is commonly sown by broadcasting (and broadcasting then requires thinning if the plants are not to compete with each other!)[206]

Planting time varies by location

There is no assigned time for planting turnips because that must be decided based on the land: some lands will make the turnips as good when planted at the beginning of August as other lands will when planted in May. The most common time of planting is a little after the summer solstice.[207]

[206] We have planted turnips just after the last frost with good success, and would add that besides the location, the variety of turnip matters greatly: some are best planted early, some late, some mature within a month or two, others require all summer. –A.B. & M.C.

[207] While experimentation will show that higher yields per plant may be achieved with thin sowing, we sometimes plant thickly for the purpose of growing sprouts or baby greens. Sprouts and baby greens are a newly popular addition to the human diet not common in Jethro Tull's time and place. Sowing thickly, then, has a desirable effect on growing sprouts: it keeps the plants immature for a longer time, and therefore increases the harvest per planting. If the farmer is skilled, they may harvest the sprouts in such a way to get a second harvest of dwarfed mature plants (another dainty not common in the 18th Century). While the dwarfed mature plants grown in this way will not exceed those grown through thin sowing, depending on the market's prices and demands, the farmer who sells sprouts, baby greens and a secondary harvest of dwarfed mature plants may earn more than the farmer who grows only a primary crop of fully grown mature plants. Sprouts, baby greens and dwarfs have also this advantage over fully mature plants: they are ready for harvest sometimes months before the fully mature plants are. By offering food months earlier in the year, a farmer can earn more total money during the year. –A.B. & M.C.

Fewer rows per bed make for larger turnips

When turnips are planted too late to have time and sun for attaining their full bulk, some drill a double row of turnips: each row being fourteen inches apart, and with 72 inches separating each double row. But I am told that in this double row the turnips do not, even in that late season, grow so large as those planted at the same time in single rows. The double row also has these disadvantages: it requires double the expense in setting out and there is fourteen inches of soil less that is hoed. Consequently the land will be less improved for the next crop.

Deep hoeing improves the effects of rain water

The rain, without the deep hoeing, does not soak the turnips very deep.

Intercropping wheat with turnips by planting in the aisles, tilling the turnip beds upon harvest

Between the rows of turnips, I have planted wheat in this manner: at about Michaelmas, the turnips having been full grown, I plowed a ridge in the middle of the aisles between rows. To do this, I took most of the soil required from the turnips (leaving only enough soil to keep the turnips alive). On this ridge, I drilled my crop of wheat and in the spring I pulled up my turnips and carried them off for cattle. This wheat, being drilled on the new ridges made in the aisles between the rows of turnips, being well horse hoed in the spring, proved a very good crop: it was drilled in treble rows with rows seven inches apart. [208]

Thin out lesser turnips so that turnips are about 12 inches apart at closest: they will sometimes grow to be bigger than that

We need not be very exact in the number or distance we set them out at within the row. Contrive to leave the master-turnips (when there is much difference in them) and leave more space before and behind them. But if there are three master-turnips too near together, take out the middlemost. The least number of turnips left in the field will yield the largest sized turnips...yet be careful not to thin too much. Attempt to retain a competent stock (which I think is not less than thirty on a square perch). The distance need not be regular for when a turnip has six inches of room on one side and eighteen inches on the other it is almost as well as if there was one foot on each side – though the distance should be equal from two turnips between which it stands.

Turnips that were so thick as to touch one another when half grown, by means of a good hoeing in their wide aisles, afterwards grew to such a good bigness that, by shutting against one another, became oval instead of round! [209]

[208] This is excellent advice, and we have included in the definition of the New Deep Hoeing Husbandry the requirement that aisles and beds be rotated annually; planting two crops at once in a way that neither reduces the yield of the other is good common sense. –A.B. & M.C.

[209] Our largest turnip thus far was 14 inches in diameter. –A.B. & M.C.

It is better to hoe aisles alternately and frequently than simultaneously and infrequently

It is beneficial to hoe turnips (especially the first time) alternately. Hoe every other row and throw the earth back again before hoeing the other rows: by this means, the turnips are kept from being stunted. It is better to have nourishment given them moderately twice than to have it all at once and wait twice as long before a repetition. Sometimes when turnips are planted late, this alternate hoeing suffices (without any repetitions) but when they are planted early it will be necessary to hoe them again...especially if weeds appear.

This alternating hoeing is of so much benefit to the turnips that four of these (which are equal to but two whole hoeings in labor) provide the benefit of almost four hoeings to the plants. When one side is well nourished, the other side cannot be starved. Yet sometimes the weeds or other circumstances may make it proper to give them a whole hoeing at first. Besides, where a great quantity of turnips are to be hoed, the last hoed may be stunted before the first are finished by whole hoeings.

In hoeing turnips, I do not think that that we can go nearer to the plants than 3 inches of their bodies[210]. The 3 inches not reached by the hoe can profitably be hoed with a bidens (also called a prong-hoe). In alternating hoeing, the hoe may go deeper and nearer to the row without danger of damaging the plants because the plant may be supported by the unhoed side. This deep plowing so near to the row is very beneficial at first but afterwards when the plants are grown large and have sent their roots far into the aisles, it would almost totally disroot them and, if they are annuals, the plants might not live long enough for a new stock of roots to extend so far as is necessary to bring the turnips to their full bigness.

But, whether providing alternating or simultaneous hoeing, there is never a danger of drying out the plants (as experience will demonstrate).

Hoeing improves drought tolerance

Dry weather does not injure horse hoed turnips as it does turnips that do not receive deep hoeing. The hand hoe does not go deep enough to keep the earth moist and secure the plants against the drought. The best season for horse hoeing is when the roots must be kept moist.

Expect yields of 12 pounds per turnip for the Great Turnip variety, with potential yields exceeding 19 pounds

Dung and tillage together will attain the necessary degree of pulverization in less time than plowing can do alone. Therefore dung is more useful for turnips because they commonly less time to grow than other plants.

I have several times heard of turnips weighing 19 pounds, and have personally known turnips of 16 pounds weight. 12 pounds may be reckoned an average size of the Great Turnips. I can see no reason why every turnip should not achieve the full bigness of the species if it is not malnourished.

[210] With skill and improved equipment (including the spader and rototiller), we till within even one inch of plants. –A.B. & M.C.

If harvesting turnips too late in the spring, the next crop cannot be planted in time and the opportunity lost is greater than the income gained by the turnips

The greatest inconvenience in the turnip husbandry is when they are fed to animals late in the spring (which is in many places the greatest use of them) because there is not enough time to bring the land into tilth for barley, the loss of which crop is sometimes more than the gain of the turnips. This is entirely remedied by my method because by my method, the land is as well tilled before the turnips are eaten (or taken off) as it is afterwards.

Planting Density

If turnips are sown in June or at the beginning of July, experienced turnip farmers will have no more than 30 to a square perch (1 every 9 square feet)[211] after they are hand hoed. When more than this is left, the crop will be less. But when drilling rows 72 inches apart, 60 may be planted per perch...though if the soil is not well pulverized or rich, 50 per perch is excessive: the horse hoe, by breaking so much more earth than the hand hoe does, can nourish 60 drilled turnips as well as 30 are nourished by the common method, which may be seen upon trial. I think that 45 is better than 60 per perch, though the number should always be in proportion to the natural and artificial pasture that will maintain them.

I have seen 60 turnips to a perch that yielded 5 pounds each make a good crop of above 80 quarters (48,000 pounds)[212] to an acre.

I have had turnips on poor, undunged land that weighed 14 pounds each, but these were only such as had more room than the rest. I have seen a whole wagon full of drilled turnips spread on the ground, and could not find one that weighed less than 6 pounds: the lightest weighed 7 or 8 pounds each. We weighed some of them in that wagon that were 14 pounds each (and they had stood pretty thick when growing in the ground!). This crop might have been growing at about 50 per perch, but grew on rich, sandy land that had been dunged three or four years before and had grown potatoes and wheat the year before the turnips were planted.

When turnips are planted late, they may be planted more densely because they will not have the time to enjoy the full benefit of hoeing (which would cause them to grow larger).

[211] 20 Perches are 1/8 of an acre. –A.B. & M.C.

[212] This far exceeds expectations of 3 tons (6,000 pounds) of hay per acre that some hay farmers hope for, and presents a viable source of calories for animal feeds: while Turnips have somewhat poorer nutrition than hay for many animals, turnips can more than adequately answer for the needs of grain and high-energy supplements that are relied upon in animal production. In comparison, Johnny's Selected Seeds, a seed breeder and seller, estimates a yield of 40,000 pounds per acre –A.B. & M.C.

Turnips are good animal feeds for cattle and sheep and can support 50 times more animals per acre than meadow or pasture can

One acre of turnips will maintain 50 times more cattle than an acre of meadow or pasture[213]. It is now so well known that cattle will eat turnips and how much milk they allow the cattle to produce that I need say nothing more about it.

Sheep will always refuse turnips at first (unless they had eaten them while they were lambs) and must be ready to starve before they will eat a turnip. Yet when the sheep taste them, they easily grow fat on them: I have seen lambs three weeks old scoop[214] them prettily when those of a year old (which are called tegs) are ready to die from hunger among them and for three or four days will not touch them...but at the last, eat them very well.

In some places, the greatest use of turnips (except for fattening oxen and sheep) is for the feeding of ewes and lambs in the spring when natural grass is not yet growing on the ground. If the sheep are turned onto their normal pastures, the meadow or pasture's crop will be spoiled and it will yield less all summer long. I have known farmers for this very reason be obliged to keep their ewes and lambs upon turnips (even those that have run to seed) even until the middle of April.

How to feed turnips to sheep and other animals I: direct grazing is unadvised as the animals will eat enough to support them all winter in two weeks

There are four ways to feed turnips to sheep. The first (allowing a flock to graze a large field without dividing it into paddocks) will not be considered: the sheep will destroy as many turnips in two weeks as would feed them all winter.

How to feed turnips to sheep and other animals II: direct grazing with moveable fences to control the rate at which the turnips are grazed

The second is to divide the field of turnips by placing hurdles along the field so that the sheep are not allowed to come upon any more turnips than they can eat in one day. Then, you may advance the hurdles further into the field daily until all the turnips are eaten. However, by this method the sheep never eat all the turnips: the sheep will leave in the ground the bottoms and outsides of the turnips they have scooped. These bottoms people can pull up with iron crooks made just for that purpose, but the cavities are tainted with urine, dung and dirt from the feet of the sheep and though the sheep do eat some of the tainted pieces, the spoiled food can't nourish them so well as that which is fresh and clean. And, the people will leave many of the turnips behind to come up among the barley: so many of the pieces of the turnips are left dried and spoiled that after the land is sown with barley, the turnips will come up so thickly that it may be seen more than half of them were left behind despite the crooks.

[213] If only one cutting (grazing) is made on the hay so that about 1000 pounds are harvested, there will be 48 times more turnips than hay per acre. –A.B. & M.C.

[214] Scooping is a process by which the animal will eat the top and the most of the root, leaving the bottoms of the root in the ground. –A.B. & M.C.

How to feed turnips to sheep and other animals III: pull the turnips out of the ground before the animals graze upon them, this will allow the entire turnip to be eaten and increase efficiency

The third way is to move the hurdles every day (as in the second way), but, so that the sheep do not tread upon the turnips, to pull the turnips up first and then advance the hurdles as far as the turnips has been pulled up and no further. By this way, there is not so much waste made as in the previous ways: the food is eaten fresh and clean, and the turnips are pulled up with less labor than their pieces would be: I have seen three laborers work every day with their crooks to pull up these pieces – which was done with much difficulty because the ground had been trodden very hard by the sheep. Instead of these three laborers, one person, in two hours time, could have pulled up all the turnips the sheep required for that day, and the sheep would have eaten them clean.

How to feed turnips to sheep and other animals IV: harvest the turnips from the field and cart them to the animals; this will allow ground to be used as efficiently as the turnips by permitting replanting and reduce disease in the sheep

The fourth way is to pull up the turnips and to carry them into some other field by a cart or wagon and to there spread every day on a new place enough turnips for the sheep to eat. The sheep will eat them clean – both leaf and root. This is best done when there is a field not far off which has more need of dung than that where the turnips grow, or when the field is too wet for sheep in the winter (some soils will, by their too great moisture and disease in the soil, spoil the sheep and give them rot). It is remarkable that the very ground that is most likely to spoil the sheep is best for the turnips: such ground will yield more and larger turnips than dry land and when the turnips are carried off and to be eaten on plowed ground in dry weather and on green grass in wet weather, the sheep will thrive much better and that moist soil that is so good for turnips, for not having been trodden hard by the sheep, will be much better for a crop of corn[215].

And, besides the better crop of corn, the savings of the expense of the hurdles and the cost of daily removing them more than compensates the cost of carrying off the turnips!

These four ways of feeding turnips to sheep are common to drilled turnips and broadcasted turnips. However, because of their weight, turnips should always be carried off for cows and oxen (both of which are well fatted by turnips and some hay in the winter)...but the management of cattle and sheep is the business of a grazier.

Jethro Tull's Supplement

Intercropping wheat, barley, oats and turnips requires good land, if land is poor, plant in wider rows and aisles

As I have formerly drilled wheat between rows of turnips, so I have since had the experience of drilling turnips between rows of barley and rows of oats, as mentioned in my Preface. I have had them in the intervals between six-feet ridges, and between four-feet ridges, and between those of

[215] Which can be planted in time onto a winter-fallowed and void field. –A.B. & M.C.

several intermediate distances, but which of them all is the best, I leave at present undetermined. I shall only add, that the poorer the land is, the wider the intervals ought to be and that in the narrow it is convenient at the hoeing to leave more earth on the side of each interval, where on the turnips are to be drilled. And this is done by going round several intervals with the hoe-plow without going forwards and backwards in each immediately, but in the wide intervals the earth may be equal on both sides of them.

Do not plant barley in rows and broadcast turnips amongst them: they stunt each other's growth

I will propose another method of drilling, which may be very advantageous to those who sow their barley upon the level, and sow turnip seed amongst it at random, as they do clover, which is of late a common practice in some places. The barley keeps the turnips under it, and stunts them so much, that they are useful in the winter or spring chiefly by the food their leaves afford to sheep, their roots being exceeding small; and for this small profit they lose the time of tilling ground, until after the turnips are eaten off, which is a damage the Anti-Virgilians think greater than the profit of such turnips.

To prevent this damage they may drill them in rows at competent distances, and horse-hoe them, and set them out as soon as the barley is off: this will both keep the ground in tilth fit for another crop of spring corn, and cause the turnips to grow large enough (especially if harvest be early, and the winter prove favorable) for feeding of sheep in a moveable fold to dung the ground into the bargain.

What induces me to propose this improvement is that a gentleman plows up his barley-stubble and transplants turnips therein, and hand-hoes them with success. By the proposed way all the expense of transplanting (which must be considerable) will be saved; and the setting out cannot be more than an eight of the labor of hand-hoeings; and I conjecture the horse-hoed turnips may be as good, for they, though stunted, having their tap-roots remaining unmoved below the staple of the land, their horizontal roots being supplied with moisture from the tap-roots, immediately take hold of the fresh ploughed earth, as soon as it is turned back to them, whereas the transplanted having their tap-roots broken off, and their horizontal roots crumbled in the holes wherein they are set, must lose time, and be in danger of dying with thirst, if the weather proves dry.

Also this way seems better than the common practice of sowing turnips once upon plowing after wheat, because the wheat land commonly lies longer unplowed by six or eight months than barley land; and therefore cannot be in so good tilth for turnips as barley land may, unless the former be of a more friable nature, or much more dunged than the latter. Besides these wheat-turnips are uncertain, in respect of the fly that often destroys them at their first coming up, which misfortune happened the autumn of 1734, to almost all that were sown in that manner.

I have observed that barley sown on the level and not hoed, overcomes the turnips that come up amongst it; but that turnips which come up in the partitions of treble rows of my rides of horse-hoed barley, grew so vigorously, as to overcome the barley. And this was demonstrated at harvest in a long field, one side of which had borne turnip-seed, and the drilled ridges of barley crossing the middle of it, and both ends of the field having barley sown on the level, one end of every ridge crossed the turnip-seed part of the field for about ten perch of their length.

I observed also that the turnips near the edges of the lands of sown barley, adjoining to the hoed intervals, grew large, but not so large as those in the partitions on the ridges, their intervals being hoed on each side of them.

But different from this have I seen shattered turnip-seed coming up in the like partitions of drilled wheat, on the very same sort of land, so miserably poor and stunted, that they scarce grew a hand's breadth high, when those turnips which the hoe left in the sides of the intervals, and at the narrow edges of the unhoed earth of the interval sides of the rows of wheat, grew large; and the wheat was good also. But I do not remember how the middle row of it succeeded.

This last experience of the turnips among the wheat was got by this accident: the wheat was drilled after drilled turnips on ridges of a different size. The turnips were all pulled up before the ground was ploughed for the wheat; but as turnip-seed never comes all up the first year, enough remained of this to come up (though thinly) in the wheat, to show exactly where every row had been drilled; whereupon the observation was made.

Supplement of the Fifth Edition

Turnip Nutrition

Though turnip leaves are delicious and nutritious fresh vegetables for human consumption, the feeding of turnip roots to animals provides low-quality high energy feed. The USDA has tested turnip roots to find the resulting nutritional values. This table is reproduced and citations provided in the Chapter on Animal Husbandry.

Nutritional Values of Turnip Roots

Macronutrients	Turnips
Calories (kcal/kg)	28
Moisture	91.87%
Crude Protein	0.9%
Fat	0.1%
Crude Fiber	1.80%
ADF	*
NDF	*
Minerals	
Calcium	0.03%
Phosphorus	0.03%
Iron	0.0003%
Zinc	0.0003%
Magnesium	0.01%
Manganese	0.0001%
Copper	0.0001%
Selenium	0.0007%
Potassium	0.19%
Cobalt	*
Sulfur	*
Vitamins	
Vitamin A, IU	0.00
Vitamin E, IU	0.05

RYEGRASS

Turnips are compared to grass hay and pasture by Tull, and so some notes should be made on ryegrass, (which is the best grass for pasture and hay).

Turnips are compared to grass hay and pasture by Tull, and so some notes should be made on ryegrass (which is the best grass for pasture and hay).

Discussion of ryegrass: differences between pasture and feed aside, the choice between feeds relies on many factors, including environmental adaptability, market values and animal nutrition; the similarity between turnips and ryegrass allow for examination of this choice

Though turnips, as Tull points out, produce greater quantities of food than grass pasture, pasture is still required for the hygiene of animals and ryegrass typically presents the best option for pasture. Such pasture when hayed is in some respects equal to or better than turnips, raising the question of how to choose between turnips and grass for animal feed and demonstrating that the farmer must consider many factors, including environmental adaptability, market values and animal nutrition, in selecting what animal feeds to grow.

Rye is as or more widely adapted than turnips are and grows as or more quickly, allowing all the advantages of a secondary crop of human food by producing hay at marginal times of the year.

Ryegrass can be either annual or perennial

Some ryes are annuals, some are perennials. Perennial ryegrass was probably the first grass to be cultivated as a pasture grass in Europe. Records of its use in Europe date to 1681. Thomas Jefferson reported perennial ryegrass as a good producer in Virginia as early as 1782, where Jefferson reported that it could yield 0.51 pounds of hay per foot (22,305 pounds per acre) (Janet Sullivan, Lolium perenne. In: Fire Effects Information System, 1992, 2009).

Both the annual and perennial varieties grow quickly. When used for hay or for pasture, more tillers are produced when clipped every 3 weeks (as opposed to every 1 or 6 weeks) during the growing season (Mahmoud, A. 1973. A laboratory approach to ecological studies of grasses Arrhenatherum elatius, Agrostis tenuis, and Festuca ovina. Shetfield, England: University of Shetfield. Dissertation).

Perennial ryegrass is slower to establish than common ryegrass, but fully developed stands are equal to common ryegrass in production and are more persistent. Establishment is, however, sufficiently rapid to allow grazing at heavy stocking levels as soon as 2 months after seeding (Janet Sullivan).

Perennial ryegrass is typically planted with clover for pasture in late winter and early spring where soil moisture is adequate for growth. Such pastures can produce up to 4,465 pounds per acre (Sullivan).

If allowed to mature, enough time is still reserved for a second crop while the farmer gains a crop of rye "berries" (good for animal or human food) and rye straw.

Ryegrass's best advantage is in pasture, where it allows a two-year rotation that improves sanitation and nutrition for animals

Yet the best advantage of ryegrass is in pasture. Besides providing good food, because it grows so quickly, it makes an excellent pasture grass allowing a farmer who does not have much room to rotate pastures slowly to institute a two year rotation.

In the first year, till up animal wastes for sanitation and plant ryegrass. By the late summer, the rye will have grown and will provide food and a sanitary turf for your animals to enjoy all winter long. In the early summer, move them to the other pasture and begin again.

In the other pasture, do the opposite: plant ryegrass in the late summer and move animals on in the early summer, off in the late summer.

Nutritional values of ryegrass

The nutritional value of ryegrass is discussed further in the chapter on animal husbandry, but a summary of its nutrients is presented here.

	Ryegrass
Macronutrients	
Calories (kcal/kg)	246.9
Moisture	0.00%
Crude Protein	19.0%
Fat	*
Crude Fiber	32.60%
ADF	25.2%
NDF	45.5%
Minerals	
Calcium	0.62%
Phosphorus	0.41%
Iron	*
Zinc	*
Magnesium	0.32%
Manganese	*
Copper	*
Selenium	*
Potassium	1.99%
Cobalt	*
Sulfur	*
Vitamins	
Vitamin A, IU	*
Vitamin E, IU	*

Rye grass has about half as much energy as alfalfa, and about one-third as much as sanfoin; it has about half as much calcium as either sanfoin or alfalfa. Yet it has more protein than either.

Effects of tillage and burning on yields

Ryegrass is typically planted in the autumn in the Southern United States, grazed upon in the winter, and tilled under in the spring. Annual ryegrass has no cold tolerance, though some perennial varieties do tolerate snow. In 1991, Carl H. Hovermale of the South Mississippi Branch Experiment Station undertook trials of ryegrass. In 1999, his *Effect of Seeding and Tillage Method on Yield of Jackson Ryegrass* was published and demonstrated, among other things, that planting ryegrass onto a well tilled field is the best course of action for a farmer, and may yield 4,148 lbs per acre (dry matter). Incidentally, a "Virgilian" burn-before-planting method was tested, and yielded just more than no pre-treatment (2,840 lbs per acre for the pre-burn). In 1993, the prepared seed bed yielded 5,324 lbs per acre; the same year, the pre-burn yielded a shameful 96 lbs per acre. Over 5 years, the well-prepared ryegrass averaged 4,492 lbs per acre.

Market value as compared to alfalfa: grass is worth 25% to 50% less

Grass hay prices are typically between 50% - 75% that of alfalfa, though often enough, grass can be worth just as much as alfalfa depending on the market. It is rare that alfalfa is worth less than grass, though. However, turnip prices are very low for animal feeds currently, and while the turnip is invaluable at producing a great quantity of nutritious energy for animals, the market farmer who would earn the greatest profit by selling their production would be smarter to use ryegrass instead of turnips, even if they only gain 4,492 pounds of hay per acre instead of 40,000 pounds of turnips.

Productive comparison to turnips: similar calories per acre are produced, but rye produces 58% more protein

In one acre of turnips, 508,023.45 kilocalories will be produced. In one acre of ryegrass hay, 503,067.87 kilocalories will be produced, a difference of about 1% in favor of turnips. In one acre of turnips, 360 pounds of protein will be produced. In one acre of ryegrass hay, 853.48 pounds of protein will be produced, a difference of about 2.37 times in favor of ryegrass. There is a similar advantage to ryegrass in Calcium yield and many other nutrients.

"Range management practices are generally based on how they affect carbohydrate reserves of grasses. For perennial ryegrass, the peak carbohydrate reserves occur just after flowering in late spring and early summer" reports Sullivan, and in this respect, there is little difference between turnips and ryegrass. However, range management practices none the less should include considerations for protein and other nutrients.

The advantage of turnips: turnips store easily in the ground against adverse weather conditions, requiring no barn. Turnips also can be turned up after all the grass has wilted and spoiled in the winter in cold wet environments. While ryegrass is favored under many other conditions, Tull found great success because turnips are best suited to the English winter

Why then should anyone raise turnips? Turnips, unlike ryegrass, easily store in the ground and in adversely moist conditions. Tull found great success in turnip farming because the English

winters were disadvantageous to winter grazing of grass: turnips could be turned up even after all the grass had wilted and spoiled, and did not require a barn for storage (as cut ryegrass hay would).

Do not rely upon it or any other one crop to feed animals: animals require balanced diets; considerations for market values drive those producers not feeding their own animals

Ultimately, a balanced diet for your animals will require several kinds of grains and vegetables or hay. While calculating feeds will be discussed in future issues at length, the farmer who is not intending on feeding their production to their own animals needs only be concerned about the costs of harvesting and the price of the market.

PASTURES

Discussion on sod-forming grasses and the relevance of rows in the beds, pasture seeding

With sod forming grasses like rye, it is neither necessary nor beneficial to institute rows within a bed. Treat each bed as a single row. Seed the rye or other sod grass in rows within the bed to ensure proper spacing as the plants mature, but understand that they will grow into the spaces between the rows. It is often beneficial to have narrow beds and frequent, narrow aisles for sod forming grasses.

We recommend trials to learn the proper width bed and aisle for your farm's individual conditions, but have found success with beds 4-6 feet wide and aisles of identical width, planting at rates of 1 seed every 9 square inches for hay, and twice that rate for pasture.

For pastures that are permanent (only temporarily grazed), we typically include white clover, sweet clover, sanfoin, wheat, oats, barley, flax, alfalfa, sanfoin, sunflowers, safflowers, radishes, and native wildflowers and weeds (especially lambsquarter and thistle) in our pasture mix. We believe it is doubtful whether the thistles are a pest, as our animals have enjoyed them so much. For pastures which are impermanent (grazed frequently or continuously, tilled under annually as described before) we plant with the rye only fast-growing foods: clover, turnips, radishes, alfalfa and sometimes beans when the climate is suitable.

The exact proportions of the planted mix should depend on the climate and needs of the animals, and it suffices to say that while these are excellent plants for us, they may not be for you.

The key is to increase biodiversity as much as possible because a pasture will not hoed: the fresh soil would be a detriment to hygiene. Strong vegetation underfoot is healthier for animals, as the resulting biodiversity and biodensity of flora and fauna is more able to decompose the waste products of the animals.

Rotation of pastures, need for permanent and impermanent pastures

Enclosing the barn, lean-to or run-in at a central location to the multiple pastures allows, through the use of gates and fences, a reduction of structural costs: each pasture, when in use, can also use the centralized shelter. We try to keep each pasture square to facilitate the use of plows and other machinery that is required when reseeding annually. Permanent (occasionally used

pastures) are kept in case the reestablishment of the annual pastures is, for whatever reason, delayed and the reestablishment requires more time: this way, the animals are not kept on overused pasture, and the reseeding of their current pasture is not delayed for the incompetence of their subsequent pasture.

Tillage in Pastures

We do not require tillage in our pastures – in fact, pastures are the only agricultural place where tillage is unadvisable. But don't we need to plow before planting to establish and reestablish pasture? Yes, it is better to do so, but in the corral or in other places where animals cannot be removed during planting, it is possible to simply harrow in the seeds after broadcasting them. If we were raising hay or other crops in our pasture we would need to till the soil frequently in the aisles, but when growing pasture, aisles are not beneficial. It is the only case when deep hoeing husbandry is not beneficial. The principle purpose of the pasture is the sanitation of the animals and bare, dirty spots are not conducive to sanitation.

Thus, pastures are best selected for those hilly lands of the farm that are unsuitable for tillage. Hills should be divided into those that face north and those that face south: the southern slopes (in the Northern Hemisphere) are best for animals because the dry out quicker and are more sanitary. They are also warmer and thus are better for winter pasture. Northern slopes are better for summer because they are cooler. Creek and hill bottoms are unsuited for pasture, but should also not be tilled: they are essential for erosion control and ecological reserve (though an orchard of semi-wild trees will do excellently there).

You should have two summer pastures and one winter pasture. Move the animals from the winter pasture in time to seed the grasses, and till up their winter pasture to plant them evenly across the field. After summer is over, the animals will find some established grasses waiting for them. The summer pasture which was depleted will be resown in the spring with the winter pasture while the animals enjoy the other summer pasture.

COW/CALF OPERATIONS: GRAZING vs. FEEDING CATTLE

The general success of the Tullian feedlot, and the strategy of using cheap rangeland for the growing of animal feed crops: possibilities of continuing the strategy today. Penning and feeding cattle is more profitable than grazing them, even on rangeland that does not yield hay or other animal feeds well – discussion on hay production profitability, wheat straw as animal feed and market dynamics for animal feed in beef production

As the inventor of the feed lot, Tull's ideas of penning animals and raising their food were as radical as they were profitable at the time, and remain profitable today.

Range land is generally more affordable than established crop land and there exists, as there did for Tull, the opportunity to acquire such affordable land, plant animal feed crops (or crops for human consumption) and either feed the crops to penned animals or sell them to neighbors who pen their animals.

While a difference between Tull and his modern imitator is that the modern imitator is likely dealing not with sheep, but with beef cattle, the strategy works today just as well as it did for Tull in the 18th Century and penning cattle is more profitable than grazing them.

Let's begin by examining the costs of grazing cattle. The principle cost is the land to graze: to get an estimate of pasture rental values, we looked at Ohio land values and North Dakota land values. We chose these two states at random, and will average them.

From Ohio State University (*Statewide Comparison of Cropland and Pasture Values*, http://agecon.okstate.edu/oklandvalues/statewide_cp.asp) we learn that in Ohio, pasture has been worth much more than crop land since 1999 (*Pasture values as a percent of cropland values through time*, 2007). There, pasture can be rented for about $11.25 per month per cow/calf pair on good to fair pasture (*Establishing a Fair Pasture Rental Rate*, *Statewide Comparison of Cropland and Pasture Values*). In Dr. Hughes' home state of North Dakota (Hughes now resides in Wyoming), pasture is rented for either 6% to 7% of the value of the land, or for $8.80 per acre per month, which is equivalent to the price asked for a cow/calf pair. To make math easier, we'll take an average, which is $10.02, but we'll round to an even $10 for easier math. Land rent is considered at $10 per month for 12 months, $120 per cow/calf pair.

In Washington State University's 2008 *Estimated Costs and Returns for a 150-head Cow-calf to Grass-finished Beef Production System in the Channelled Scablands Range Area of East-central Washington*, (by Drs. J. Shannon Neibergs and Donald D. Nelson) the cattle are fed through the winter. This is a fairly typical behavior of ranchers. With hay prices at $120 per ton, this resulted in a per-head cost for the feed of about $1 per pound sale weight. It also resulted in a net loss per head of cattle. However, we will, out of generosity, presume that there is enough pasture for the animals in the winter and thus avoid demonstrating too quickly that the Tullian method of penning animals and feeding them with cultivated hay is more profitable than grazing them.

Labor will also not be considered, as there is almost no labor cost to the round up (harvest), and while some ranchers indulge a veterinarian or cowhands to help with calving, many do not. Labor would be significantly higher if cattle were driven from pasture to pasture, but as this so favors Tullian production, it may be forgiven by proponents of grazing cattle to forego the inclusion of labor costs in driving cattle or keeping them on a pasture.

Trucking costs should be considered. Washington says calves cost about $10 per head and finished animals cost about $17 per head to truck when the animals are transported 150 miles.

All told, the rancher spends for a finished, 850 pound animal $987 if hay is bought, but since we are generous, we will estimate only the costs of land and trucking: $137.

Washington explains in their excellent work that in May of 2008, the rancher could expect a price close to $0.90 cents per pound in a survey of average monthly prices in Texas-Oklahoma, Kansas, Nebraska, Colorado, and Minnesota for grass-finished live steers (www.lmic.info/tac/spreadsheets/spreadsheets.html). This falls somewhat short of a break-even price of $1 per pound, though trends are demonstrating efforts in marketing to raise the demand for grazed beef are being met with positive responses.



We'll say that the rancher, before winter hay is considered, earns $137 per acre.

While we could quickly note that the farmer can earn much more than $137 per acre growing wheat (or nearly any other food for human consumption besides beef), we put aside this objection with excuses that the land may not receive enough water to yield wheat or other food, and we will examine the growing of hay to feed penned animals to seek to understand whether the farmer is wise to raise cattle instead of crops.

What can grow in the deserts of Washington? Oklahoma State University Cooperative Extension reports in *Alfalfa Needs a Lot of Water* (http://alfalfa.okstate.edu/webnews/water1.htm) that "as a general rule, alfalfa needs about 6 inches of water in the soil, available to the roots, for each ton of dry matter per acre...If your soil can store 2 inches of water per foot of depth and roots go down to 10 feet, you should be able to produce about 3.3 tons of hay per acre." Sanfoin's requirements are similar, and it is recommended by Montana State University in the *Montana Interagency Plant Materials Handbook* by Drs. Smoliak, Ditterline, et al. that at least 12 inches of water be available for sanfoin. That turnips probably would not be appropriate for the deserts of Washington needs no further discussion. Without the advantages of Tullian farming, the prospects for cultivating any non-desert plant is slight.

The 7 to 10 inches of rainfall received by Washington State's example is indeed dry.

Tullian farmers need 3 times less water per plant and need not resort to raising cattle on dry lands, and earn greater money by feeding the cattle of their neighborhood

Thankfully, Tullian farming results in 3 times as much water per plant (because there are 3 times fewer plants per acre with 75% of the area taken up by aisles, and only 25% in beds; even if the area is divided evenly between beds and aisles, this results in twice as much water per plant). Needless to say, Tullian agriculture not only increases soil water and soil water capacity, but also soil water per plant!

Even Indian corn, well spaced, can yield well in such desert conditions. Polycultural intercropping with squash and beans at the base of the corn further improves land yields: such planting was undertaken by native Americans for generations without irrigation. Corn, beans and squash were planted deep in a single mound, and mounds were sometimes spaced even a dozen feet apart. Certainly, if Indian Corn can grow, alfalfa can.

Being able to relate all environmental concerns equal, we will presume for this comparison that the farmer is able, whether in the deserts of Washington or the fertile fields of Ohio, to produce 3.3 tons per acre in hay. This is a low number, because Tullian methods, both a response to greater water and greater food would enjoy greater yields. Nevertheless, the hay farmer is earning (at Washington's $120 per acre) $396 per acre. This would come at a cost of $12 for 4 hoeings (At 2 miles per hour, and at $8 per hour, with 18, 6 foot beds per acre, each square acre will costs $3. Done four times, this is $12), a profit of $384 per acre before harvesting. With harvesting amounting to about 25% of the value of the crop, this results in net profit of $288 per acre.

This is 2.10 times greater than the farmer would earn by their cattle (again, generously supposing hay is not bought for them in the winter). It is, of course, much greater than the loss a farmer earns from their cattle should they feed them in winter. This is also about 29 times greater than the revenue the farmer would earn by renting their land to a rancher at $10 per acre.

If the farmer were to then store the hay under the shelter of a barn as Jethro Tull did, they would find the practice profitable. Dr. Edward B. Rayburn of West Virginia University's Extension Service calculated in his *Round Bale Storage Costs* the costs of sheltering 1,200 pound bales of hay. A table from his report examining the losses from various methods of storage is reproduced here:

Effect of storage method on storage losses from large round hay bales

Storage Method	Dry Matter Loss Range	Average
Barn	3-8%	5%
Additional losses with outside storage		
Covered on pallet	5-10%	8%
Uncovered on pallet	28-39%	34%
Uncovered on gravel	4-46%	22%
Uncovered on ground	7-61%	33%

If a barn costs $5 per square foot, and hay is worth $120 per ton (each bale being 0.66 tons and worth $79.20) and each bale occupying 25 square feet, the hay is worth $3.17 per foot. Stacking the bales three high, this increases to $9.51 per foot. The barn, saving 28% of this value per year over open storage ($2.66 of hay per square foot), the barn is paid for in just under 2 years without accounting for the higher value of the hay resulting from proper storage.

And the hay would, likely, be worth more because of its superior condition.

If the farmer fills up their barn and stores hay outside by putting it on pallets and covering it, the cost of a tarp can be as little as $15 for a new pallet, and $40 for a new tarp: a total cost of $55, or $2.20 per foot. This amounts to a savings of 25% over storing hay in the open ($0.79 per foot, if the hay is stacked only one high), and the tarp and pallet are paid for in just under 3 years, even with hay so undervalued.

The farmer of 100 acres who, instead of grazing 100 cow/calves, pens them into 1 acre and raises hay on the other 99, will produce 326.7 tons of hay, earning (at Washington's $120 per ton) $39,204 to pay for the food for $41,100 in cattle. Should the farmer sell the hay to themselves to feed

the cattle, this allows 20 pounds of hay per cow/calf per day if they are kept a year – this is about their maintenance requirement of 20 pounds per day (2% of their 1,000 pound combined body weight).

And here we must bring into question whether the unpenned cattle would have as good weight gain and be worth as much upon sale with only 1 acre of pasture per year for a cow/calf and why the grazier would prefer to earn less per acre with the cows than by planting crops? Hay grown without cattle trampling it and eating it yields more hay than that which is not so harassed.

Even with the cost of trucking computed, the grazier ought to raise hay or some other crop and pen the animals off their field. In *Dairy Today* (June / July 2006), Gary Freeberg of Freeburg Hay Company reports that trucking can cost $2 per mile with diesel fuel prices at $3 per gallon. Shipping 50 miles, this decreases profits of alfalfa hay from $288 per acre to $188 per acre, nearly to that of wheat and still much more than the yield of a cow/calf operation per acre.

If such a farmer should forego both cows and hay and raised wheat, they would earn $161.34 per acre and more than if they were simply grazing cattle. Is this reason to forego animal feed?

Probably not: such a farmer might also take the time to consider their hungry animals, and harvest the wheat straw as well.

Dr. Herb Ohm and Dr. Jim Camberato of Purdue University report in *Wheat Management in Indiana 2008* that about 100 pounds of wheat straw are yielded with every bushel of wheat, though only about 2/3 of that is actually baled (a total of 66 pounds of wheat straw per bushel of wheat). With about 29 bushels of wheat harvested per acre, this amounts to 1,914 pounds of straw, or 0.87 tons of straw. Wheat straw is typically worth half of alfalfa, and at a price of $60 results in $52.20 per acre, $39.15 per acre after harvesting costs. Adding the wheat straw back into the profit of wheat, a total of $200.49 per acre is achieved. More than 25 head of cattle could be fed 20 pounds per day off the wheat straw from 99 acres for a bonus yield of $3,425... but it is doubtful the farmer would exchange $19,848.51 in wheat straw for $3,425 in beef.

A wheat farmer who uses the straw from 99 acres to supplement the feeding of cattle will earn more than a cattle rancher would raising cattle on the land, but a wheat farmer still earns more per acre without cows considered. As there were too many sheep in Tull's day for the public's good, there are simply too many cattle today, and a farmer does best by feeding the cattle of their neighbors who don't know it and will pay richly for the hay.

An alfalfa farmer will likely earn more than 3.3 tons per acre, and will earn much more than a wheat farmer could on the same land. The reason is simple: graziers cannot feed their cattle on their acres without raising additional hay and must buy animal feeds from a farmer.

Pen cattle in very large pens so the animals can hygienically roam and exercise

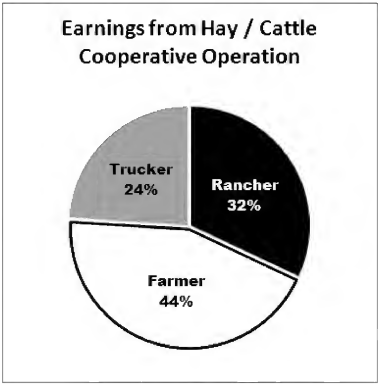
There is some argument to stocking a pen of cattle so thinly as 1 animal per acre, or less: it preserves the grass under the feet of the animals, and keeps it somewhat more hygienic by reducing mud and filth; it is also seen as being somewhat more humane to the animals, allowing them room to exercise and play in. In this sense, penning cattle beyond this point is unacceptable, and the rancher who buys hay is, instead of penning their cattle on 1% of their land and growing hay on 99% of their land, penning their cattle on 100% of their land and grows hay on none of it, outsourcing the growth of the hay to confederates who earn a portion of the final beef price in exchange for feeding the penned cattle. The consumer of beef pays for this decision by meeting the price dictated by the rancher, indicating it is the public's will that the animals be treated so well.

In these large pens the rancher will sometimes overstock somewhat, and rotate the animals from pasture to pasture, taking the time and effort to either till up and reseed damaged pasture, or simply allow nature to recover the compacted ground. Usually, manure is harrowed and integrated into the turf. When pasture is rotated, the number of animals that land is known to be able to bear can be increased: pasture can withstand a certain amount of punishment, and an intense amount of punishment for a short duration is equivalent to a lesser degree of punishment over a longer duration. In most places, a cow may be tolerated on an acre of pasture indefinitely. Thus, a cow on a half acre may be tolerated for a half year, and a cow on a quarter acre for only 3 months. Several goats or sheep are held to be equivalent to one cow, and some animals (such as chickens) are in many cases entirely harmless to the pasture no matter their density.

By this understanding, truly grazed cattle are very rare indeed: such are those cattle which rely on no winter feeding, which are on lands large enough to provide for their numerous herds: it is more profitable to intensify animal density and provide food to them, just as it is more profitable to intensify plant density (in the beds) and then provide food (in the aisles) to them.

Hay and cattle operations (and the trucking operations that unite them) can be viewed as a single unified operation of growing hay and feeding cattle, with the division of the profits from the sale of the beef divided between the rancher, the farmer and the trucker who transports both hay and cattle, favoring the farmer significantly, encouraging the farmer to relocate operations close to the rancher to earn a larger share of the trucker's income

Examining the hay and cattle operations as a single unified operation of hay, feeding that hay to cattle and the transportation between hay field and cattle results in a total per-acre earning of $137 from cattle, $188 from hay and $100 from trucking, a total revenue of $425 per acre. Thus, the rancher earns 32% ($137 / $425), the hay farmer earns 44% ($188 / $425) and the trucker earns 24% ($100 / $425).



From this relationship, we understand that the farmer's services are in greater demand than the rancher's, that the rancher is dependent upon the farmer and willing to give bonus money to the farmer to persuade them to grow animal feed instead of human food. We also understand the need for the trucker: the growth of hay occurs at a significant distance from the rancher. Much of the trucker's income goes to pay for fuel.

Farmers choose the best land to farm on, not necessarily those which are closest to the demand of ranchers (which is typically poorer land), however, with Tullian agriculture and animal-power, so-called marginal lands are well suited for agriculture and the farmer who foregoes the tractor and undertakes traditional Tullian agriculture stands to earn more per acre

The reason why hay is grown so far from the rancher is because the pasture lands are necessarily less fit for agriculture. Farmers choose the best lands to farm on, and leave the rest to the rancher whose cattle need only a decent place to stand upon, being fed the balance of what the land will not yield.

How much of the distance is due to the large tractors that the modern hay farmer relies upon requires examining how the adoption of the large tractor (post World War II) in the last half of the 20th century changed or did not change the relationship of farms and ranches, but it certainly urges the farmer to raise their hay as close to the cattle as possible to earn a larger share of the revenue from the trucker.

Impact of the tractor on the geographical relationship between hay and beef production centers and national land use – Like in the 17th Century, the pastures and marginal lands present a great opportunity for Tullian farmers who would raise animal feed for their cattle-grazing neighbors. Rangeland has decreased and farmland has remained constant since the development of the tractor because much of the retired rangeland is no longer suitable for crop production with today's technology...even though it is suitable for Tullian technology

Dr. Cynthia Nickerson of the USDA ERS reports in her 2005 *Land Use, Value, and Management: Urbanization and Agricultural Land* that "Census-defined urban area grew by about a million acres (4 percent) per year since 1960. The rate of increase dropped from 3.5 percent per year in the 1960s and 1970s to 1.8 percent per year in the 1980s... Cropland acreage has remained stable over time, straying only 4 percent (plus or minus) from the 463-million-acre average seen in 1945-97. Agricultural output has increased steadily, by nearly 2 percent per year since 1948."

About half of the acres in farms are not classified as cropland, and the number of such acres in agricultural uses has declined over time. Most of these acres are rangeland and not suitable for crop production with today's technology. However, some of these noncrop acres, and others in rural uses, could be converted to cropland if market conditions were favorable. Estimates of the rate of conversion of rural land to urban uses vary depending on the data source and the time period examined.

According to the Major Land Use series, conversion averaged 1 million acres per year from 1950 to 1992. This rate increased to 1.4 million acres per year from 1992 to 1997. However, total urban area was still less than 3 percent of the total U.S. land area in 1997. Rural land includes a component used for residential purposes that is not farmland or urban area. This rural residential area was estimated at 73 million acres in 1997, an increase of 17 million acres from 56 million acres in 1980. Rural residential land occurs mostly on large lots—20 acres and greater.

Land in rural areas is generally less expensive than urban land, which likely accounts for the larger lot sizes in rural areas. Conversion to urban uses is largely irreversible—land seldom reverts back to rural uses once converted to urban. Some rural residential land, however, could convert to other uses, such as cropland, if commodity prices climbed. The highest physical quality of land for agricultural purposes, prime land, has been converted to urban uses at approximately the same rate as agricultural land not classified as prime land.

Although conversion of rural land to urban uses is most likely to occur in metro counties, where the proportion of prime cropland is higher than in nonmetro counties, only about one-quarter of all prime cropland is in metro counties. Further, fast growing areas (such as Florida and Arizona) are not areas with high concentrations of prime land. While urbanization is not threatening our ability to produce food and fiber, society may choose to protect farmland for a variety of reasons, including preserving a local way of life, safeguarding rural amenities, or minimizing congestion.

And this gives Tullian farmers opportunity. Rangeland, unsuitable to today's technology, is as acceptable for today's Tullians as it was for Jethro Tull himself who farmed on pastures. These pastures are affordable and good for those who would till aisles, and the improvement to the local ecology will be seen as a boon to local governments:

Despite the relatively small fraction of the American landscape dedicated to urban uses (3 percent or less), there is growing concern about the disappearance of farmland in some parts of the country. While interest in protecting farmland arises in part from desires to maintain crop production, many citizens want to protect farmland to preserve nonmarket benefits. These 'rural amenities' include:

Environmental Amenities: open space, soil conservation, biodiversity, wildlife habitat, recreational opportunities, scenic vistas, isolation from congestion, watershed protection, flood control, groundwater recharge

Rural Development Amenities: rural income and employment, viable rural communities, diversified local economy

Social Amenities: maintaining traditional country life, maintaining a small farm structure, maintaining cultural heritage.

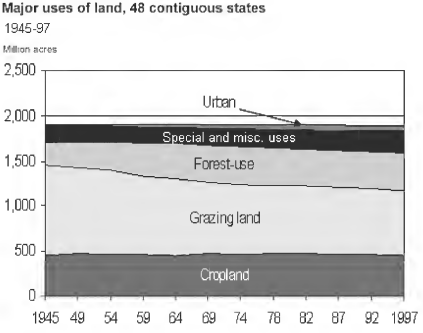
These rural amenities are often a byproduct of the agricultural production process. Ensuring the continued availability of these rural amenities may be the most important reason for farmland protection, especially for farmland protection near urban areas. Consequently, information on the relative importance of these rural amenities can be useful when considering the current state and future direction of farmland protection programs.

The effects of farmland protection on the provision of rural amenities has received little attention. Despite the numerous programs nationwide to protect rural open space and to preserve farmland, very little is definitively known about which individual rural amenities taxpayers really care about when they support farmland protection programs. A recent ERS report examines farmland protection programs to see what importance the public places on various reasons for protecting farmland.

Given that farmland protection programs can be expensive to implement, understanding how the public values rural amenities can be crucial in determining preservation priorities.

Some tentative conclusions as to the importance of "farming" in farmland protection programs can be drawn. Farmland protection programs largely focus on the protection of active agriculture, with many programs favoring the preservation of productive soils on which field crops are typically grown. This strategy holds implications for the set of amenities that are likely to be preserved in these programs. For example, emphasizing protection of cropland versus pastureland yields different scenic views, and has different implications for water quality, wildlife habitat, and other environmental amenities. It also implies a tradeoff between long-term survival of some form of agriculture, at the possible cost of providing a mix of rural amenities that is less than optimal today.

Expensive government programs to support and promote agriculture are not needed when the Tullian is willing and able to use their affordable equipment to bring pastureland into farmland through small and micro farms. These can be closer to the ranches that need hay, reducing transportation costs and earning both farmer and rancher greater revenue.



Source: Major Uses of Land in the United States, 1997

The decline of grazing land is progressive and related to the increasing efficiency by which cattle are fed by farmer-partners who grow the hay needed to sustain the cattle over winter. While recently more has grazing land has been made into forests than into farmland, it is reasonable to suppose that soon there will be an increase in cropland as more farmers learn how to use grazing land to advantage through Tullian methods.

FRUIT AND VEGETABLE FARMING

Turnips are a kind of vegetable, and vegetable and fruit farming for human consumption was not popular in Tull's time, such foods were typically imported from the Continent until just recently. However, we believe that such notes on the production of turnips and other vegetables would naturally be annexed to the chapter to turnips and have included them here. –A.B. & M.C.

Fruit and vegetable production and consumption was not common in England until after Henry VIII (about 1547), this shaped modern eating habits against fruits and vegetables; also, basic biological instincts discourage people from seeking the fruits and vegetables necessary to their health

David Hume, in his *History of England* (volume iii) reports that it was not till the end of the reign of Henry VIII (about 1547) that any salads, carrots, turnips, or other edible roots were produced in England. The little of these vegetables that was used were imported from Holland and Flanders. Queen Catherine, when she wanted a salad, was obliged to send a messenger to the continent for that purpose.

While this fact creates a humorous episode in Mark Twain's *the Prince and the Pauper* (a story about Henry VIII and his successor, Edward VI) wherein an imitator of the young prince is requested by his prince to trade places so they each might better learn what the their different classes live like, and the imitator is presented with a turnip at a royal feast and is not actually sure what it is, when modern fruit and vegetable farmers in the United States and elsewhere are confronted by customers who are not exactly sure what fruits and vegetables are, the humor of the situation is lost and the event becomes a tragedy.

Yet, however tragic, it is true that many modern Americans are simply unsure how to use the delicious, nutritious vegetables and fruits presented to them. The lack of fruits and vegetables in the 16th Century English diet greatly affected the American diet of today, and it is one of the principle problems which present the true nature of fruit and vegetable farming: these foods are necessary for health, delicious to eat, easy to produce, affordable to buy, and almost entirely undemanded. Malnutrition now strikes America and the world as people starve themselves in the midst of plenty.

In this chapter, we will explore the reason behind this starvation, and present options for the farmer to improve sales of fruits and vegetables.

The reason why fruits and vegetables remain unpopular is not because of 16th Century gourmands (though their culinary tastes do not help the vegetable or fruit farmer), but because of a basic biological instinct that drives people away from eating those foods most nutritious and necessary for them. This instinct may be overcome.

But first, the Tullian adaptations to fruit and vegetable farming should be discussed.

Difference between Tullian and conventional farming methods: a discussion on intensive and non-intensive polycultural intercropping. Tullian agriculture easily facilitates intensive polycultural intercropping and land becomes more productive because of this. Example of Tullian vegetable/fruit farming

Tullian methods allow for easy polycultural intercropping and the raising of crops that take less than a season to mature. The high values of fruits and vegetables grown in this way are, initially, appealing to the farmer who is debating raising cattle, grains, turnips or other animal feeds, but inquiry quickly demonstrates that there is no advantage to raising fruits and vegetables, grains, cattle or animal feeds.

The farmer who raises crops which do not require a full season to mature, the farmer who sells to buyers that require a constant supply of a variety of fresh produce, and the farmer who owns very little land should undertake intensive polycultural intercropping.

Definition of Intensive, Polycultural and Intercropping can include grain production as well

Intensive agriculture describes agricultural methods that result in more than one crop planted and harvested per season, and also includes those methods that result in several planting and harvesting seasons per year.

Polycultural agriculture describes the cultivation of more than one crop at a time.

Intercropping is the method of planting more than one crop in a single bed.

Intensive, polycultural intercropping is undertaken in the Tullian method by seeding several crops in the beds at once, and harvesting those that mature first in such a way that they make room for those that mature later and last. When the summer season is over, an autumn planting can be undertaken if the beds are tilled.

While there is infinite variety in the farmer's options, a typical plan is to harvest *sprouts or baby greens, salad crops or spring herbs or spring vegetables, annual vegetables or annual herbs or annual fruits, and then end the season with a second harvest of sprouts and salad crops or autumn herbs or autumn vegetables.*

Occasionally, grains or potatoes are substituted for the annual fruits, but this usually prohibits a second harvest of sprouts or baby greens and salad crops, autumn herbs or autumn vegetables and results in non-intensive, polycultural intercropping.

Polycultural intercropping, whether intensive or non-intensive, somewhat reduces yield by reducing the amount of food per plant, and is therefore generally employed by those farmers who do not own enough land to grow each kind of crop in its own bed and still meet the requirements of the contracts they enter into. In example, a farmer may not have an acre for sprouts, an acre for spring vegetables and an acre for annual fruits (3 acres total), but does have one acre for all three.

Farmers raising fruits or vegetables has great need to produce a constant supply of crops during the year – an example year's production

The contract or market that requires multiple crops grown for continual produce in a year is a necessity for some farmers.

We will examine first a typical season and then an "extended" season, which will include a winter planting and harvesting, examining costs and potential revenues to illustrate the example. The example will be undertaken on 100 feet of a 6 foot wide bed.

Seed prices are estimates based on 2009 prices from Johnny's Selected Seeds, an excellent breeder and seller of seeds. The price was rounded to the nearest quarter dollar, as the price is highly variable. The value of mature crops is based on the Agricultural Marketing Service of the United States Department of Agriculture (http://www.ams.usda.gov/). We did not look at "organic" prices, but at conventional prices. The sale prices were rounded to the nearest quarter dollar, as the price is highly variable.

Spring:

Plant Sprouts. Peas are planted, at a rate of one seed every 4 inches in a row, rows spaced every 2 feet: 9 seeds per bed foot. The crop is expected to be ready within 2-6 weeks. It also bears mentioning that higher or lower densities of any particular crop could be selected: if the sprouts are in higher demand than the spinach, less spinach would be planted and more sprouts would be planted: sprouts can be planted at a spacing of zero inches: literally next to each other.

900 seeds for the area cost ‹$0.50›

Harvest Sprouts. 900 sprouts. Though the size and weight will depend on the farmer's discretion, some waiting to harvest until the leaves fully emerge, others harvesting right at the emergence of the stalk, we'll estimate 20 peas are required to fill a cup, and a cup weighs 2 ounces. $4 per pound sale price.

(900 peas / 25 per cup) x 2/16 lbs x $4 per pound $18

Plant Spring Vegetable. Spinach is planted, with the intention of raising it into full sized heads. It will take about 2 – 3 months for this maturity. Spinach should be planted about every 4 inches in a row, and rows are to be spaced every 2 feet: 9 seeds per bed-foot.

900 seeds for the area cost ‹$0.50›

Plant Annual Fruit. Zucchini is planted with the intention of harvesting in late summer. While actual harvesting will be undertaken in early, mid and late summer, for the ease of this scenario, it is presumed all the zucchinis will be harvested in late summer. *Also, we will not count the harvest of squash blossoms in early summer and late summer* as this quantity harvested depends on the farmer's objectives for fruit production and the relative price of blossoms to fruit. As the squash grows larger, it will require more space and would begin to overshadow the spinach and sprouts, except that they'll have been harvested long before hand. The width of the beds allows the more powerful roots of the squash to reach the aisles. Because typically only 1/3 of seeds are viable, 3 seeds will be planted at once, every 24 inches on a row, with a single row on one of the two middle rows of the 4-row bed. This results in 150 seeds for 50 plants on the 100 foot long bed.

150 seeds for the area cost ‹$0.50›

Early Summer:

Harvest Spring Vegetable. 900 plants, each weighing approximately 2 ounces (which is low, but ideal for this estimate: we have had spinaches weigh as much as 8 ounces in good years), valued at $0.75 per pound.

900 x 2/16 lbs x $0.75 $84.38

Late Summer:

Harvest Annual Fruit. 50 plants. Whether allowed to grow large or harvested premature, the plant will yield about the same pounds of fruit. While we estimate for ourselves 10lbs of fruit per plant, we have had plants yield more than 30lbs on good years; yet 4 lbs per plant is typical for most farmers and we have used this figure here. Valued at $0.75 per pound, rounded down from $0.85.

50 x 10 lbs x $0.75 $150.00

Autumn:

Plant Sprouts. 900 seeds for the area cost ‹$0.50›

Harvest Sprouts.

(900 peas / 25 per cup) x 2/16 lbs x $4 per pound $18

Plant Spring Vegetable. 900 seeds ‹$0.50›

Harvest Spring Vegetable.

900 x 2/16 lbs x $0.75 $84.38

Summary:

Seed expense ‹$2.50›

Tillage, hoeing and Seeding:

At 2 miles per hour, and at $8 per hour, each pass costs $0.08. With 10 hoeings and tillages and 2 seedings:

$0.08 x 6 ‹$0.96›

Irrigation water:

The cost of irrigation water varies greatly and depends also on the crop's requirements. An expense of $10 per 1000 gallons, a high number, can be examined: watering at a rate of 5 gallons per minute for an hour once every week results in 5 gallons x 60 minutes = 300 gallons, a value of $3 per week. In a 7 month growing season, this results in an expense of

7 months x 4 weeks x $3 ‹$84›

Harvesting

Cost depends on crop and is not factored in: can be as little as $0.67 for harvesting corn with human hands ($8 per hour, 5 minutes per 100 feet). Could be significantly higher. N.D.

Revenue $354.76

Profit for 100 feet: $267.30

Profit per acre:
An square acre has 209 feet per side, or 52,100 foot long 4 foot wide beds and aisle pairs

If there are 25% beds and 75% aisles
(this would certainly have greater yield per bed, because of the increased food supply per plant)
(13 beds x $267.30 per bed) $3,474.90
If there are 50% beds and 50% aisles
(typical)
(26 beds x $450.59 per bed) $6,949.80
If there are 75% beds and 25% aisles
(not recommended, but possible: this would decrease yield per bed somewhat because of there being less food per plant)
(39 beds x $450.59 per bed) $10,424.70

Fruit and vegetable farmers must choose between high value and low value crops and must choose how to market or process those fruits and vegetables to ensure maximum value: if properly marketed or processed, typically low value crops can be worth more than high value crops.

This is a simple combination of plants intended as an example. More complicated combinations exist: corn and beans could easily be intercropped with the zucchini, as they not only do not compete, but enter into a symbiotic relationship with each other. This would yield a "bonus" crop not totaled in before. In example, corn can be planted in the second middle row at a rate of 2 seeds every foot for an additional cost of $0.50 would yield at least 50 ears, which, when sold as a fresh "sweet corn" vegetable at $0.25 per ear to bring an additional $12.50. And green beans, seeded at a rate of 3 seeds per row-foot on the outside rows will yield about $56.25 if each plant yields 3 ounces (again, a low figure, but one that is, however unfortunately, standard). This brings the total income per bed up to $335.05.

And there are so many different crops to choose from! From delicious fava beans to exotic colors of beets, from pear-shaped yellow tomatoes to carrots, the kinds of vegetables and fruits are very numerous, each one with its own market value.

Planting more than one crop in a bed requires narrower beds so that all the crops can eat from the aisles easily. When many crops are planted in a bed, the roots of those on the outside of the bed form a barrier to those located in the inside of the bed. While the farmer ought to undertake their own trials, we have had success with 4 foot beds when more than 5 crops are planted per bed.

If the farmer is able to sell "retail" instead of "wholesale," directly to the consumer, they may charge much more, easily earning twice the value of the wholesale market. However, retail farmers have additional expenses of marketing that reduce the increased revenues significantly.

Some varieties of the same plant sell for more than others as well: for example, not all zucchini are the same. "Costata Romanesco" zucchini, which is a variety from Italy that is also harvested as a winter squash, cooks nicely, staying firm, and is also easily made into zucchini chips, and sells for twice as much as regular zucchini. And the demand for marbled tomatoes allows for a sale price sometimes twice that of standard red tomatoes.

Processing can also change the value: dried sliced zucchini "chips" are worth more than the fresh whole zucchinis, even after processing is considered.

Demand for fruits and vegetables is highly variable, but there is nothing that Tullian or any other method of agriculture can do against this

With vegetables and fruits there is so much more to be concerned about than whether a crop will be brought in.

Indeed, whether the crop will mature is the least of worries for a Tullian farmer. We have only once had a crop failure using Tullian methods, and that was due to criminals intentionally destroying our crops. That it required so much effort on their part to destroy our crops is some solace (they grazed cattle on the crops but the cattle walked in our aisles and ate our weeds, they then tried pigs, but they stayed to the aisles and ate only those crops which had already been harvested and needed mowing before being tilled under, they then put horses on the field, but these politely stayed to the aisles and ate the few grasses growing among the vegetables. Failed by their unwilling animal conspirators, they tried to herbicide our crops but our crops were strong and resisted the herbicide nearly perfectly. Eventually, they had to cut out our vegetables with shovels to kill them).

Once, a neighbor's horses innocently escaped and romped through our vegetables, rolling in the midst of them. Our vegetables recovered from this insult, and we had no hard feelings towards the neighbor.

A fellow tenant, desiring our field, once tried to graze her horse on our crops at night. But, no sooner was the horse put in the pasture than our friendly coyotes that had built a den in the corner of our field, came out and spooked the animal, and the horse leaped the fence and ran behind the landlord's house and onto the road, waking everyone up and betraying the crime.

No, we are not frightened by damage to the crops, but market uncertainties do occupy our thoughts.

Dr. Greg E. Fonsah of the Department of Ag & Applied Economics at the University of Georgia in his 2003 essay, *Vegetable Wholesale Price Trend* describes what does concern us when we raise fruits and vegetables.

"One of the major problems facing vegetable growers is price fluctuation. Vegetables are highly perishable with a short shelf life. Good pricing is an essential component for profit maximization. If the prices are good, the gap caused by the high cost of production is narrowed and profitability is improved. The reverse is true when depressing prices set into the equation.

In order to select pricing objective, it is important for the farmer to decide the target market. In the vegetable industry, most farmers or companies adopt the survival objective strategies due to (1) fierce competition, (2) increasing changes in consumer wants (3) overcapacity, (4) increasing regulations on input and chemical applications and (5) consumer awareness and health conscious attitude. Unfortunately however, the survival strategy is short-run incline. As long as the farmers can cover their variable and a portion of their fixed costs, there are still in business.

Vegetable wholesale price trend is an important guide to farmers as well as financial institutions. It is a guide for production and marketing decision aid. Unfortunately, price trend is so volatile and fluctuating that predictability is impossible. Most of the time, growers have to utilized their gut feelings or simply "take the bull by the horn", so to

speak, and get on with their business. There may also be variations depending on the targeted market." — from www.ces.uga.edu/Agriculture/agecon/budgets/printed/vegtrend.pdf

Several of Dr. Fonsah's concepts are very striking: vegetable farmers have survival as their objective, that they accept covering only their variable and a portion of their fixed costs. Contracts made by growers are usually with a buyer directly, and those which have the misfortune to sell on the open market have no idea what prices will be like when their product is ready to sell because the market itself does not function to allow fruits and vegetables to act as atomistic commodities: despite grades of produce, each lot is sold as a slightly different quality because the grades are so broadly inclusive as to be worthless.

All farmers earn about the same profit per acre, no matter what is grown, when all costs are considered – especially those of spoilage and marketing

Just as all laborers earn about the same wages per hour, when the costs of training, equipment and other capital investments are considered, all farmers earn about the same per acre when all capital investments and costs of marketing are considered. The exceptions exist when bonuses are offered to farmers to provide those products that are severely demanded (such as hay, medicinal or narcotic crops) or those which are exceedingly difficult to grow.

Tullian wheat farmers (as discussed in the chapter describing the difference between the old and new husbandries) can earn about $161.34 per acre. Tullian vegetable farmers can earn about $6,949.80 per acre. Yet, even though vegetable farmers are earning 43 times more per acre than Tullian wheat growing farmers, this does not mean that they are keeping all of that.

Vegetable farmers have greater risks of spoilage and higher costs of marketing than wheat farmers, who do not need to spend any money on marketing more than transportation, and who face (almost, by comparison) no risks of spoilage. Additionally, the vegetable farmer has greater price and demand volatility than the wheat farmer, and has to earn more with each harvest in case price or demand decreases suddenly. This results in the vegetable farmer needing to earn 43 times more than the wheat farmer to earn a similar profit margin.

To look at this another way, if a farmer could earn 43 times more profit growing vegetables and fruits, there would be few wheat farms.

Vegetables are not severely demanded, in fact, the opposite is true.

It is difficult for fruit and vegetable farmers to hold harvests until prices improve, but some processing methods allow this luxury, and some marketing methods (such as the CSA or buyer's cooperative) improve the constancy of demand, standardized grading often improves demand

Vegetables and fruits are risky business. At least with Tullian agriculture, the farmer is assured that they will get a sizeable crop, even if they do not know how much it will be worth. And, they will have far less fixed costs than their "fierce" competitors do: so let the competition worry whether people will come back. Let the competition drive the market high to cover their fertilizers, pesticides and herbicides (which can amount to more than 40% of their variable costs). Let the cost of production for your competitors include extensive labor for weeding, celebrated equipment and other unnecessary expenses. Let the competition's failure leave the buyer hungry enough to pay

more. You will be able to sell for less, and even feed the children of the poor, and earn both honor and wealth for doing so.

Some vegetable farmers reduce risks of spoilage by processing their produce into more preserved states: zucchini can be dried into chips, mushrooms dehydrated as well. Berries can be made into preserves or dried fruit, or pies. Freezing and refrigeration is also used to preserve against spoilage. But fresh produce will always cost more than preserved produce because of spoilage.

A recent innovation has been made to reduce the price volatility: farmers now create cooperative associations with the buyers so that they purchase a share of the harvest through a corporate entity known as a "community supported agriculture," or CSA: the farmer, effectively, becomes a sharecropper on their own land, working for sometimes hundreds of people who each own a share of the crop. This also reduces spoilage, as the produce is delivered fresh from the field. Whatever is not contracted in this way is sold to distributors at wholesale prices – if the distributor is buying.

The lack of those excellent and reliable markets that wheat farmers have found safety in is a weight upon the minds of every fruit and vegetable farmer. With useless grades that prevent the successful commoditization and atomization of fruits and vegetables, prevents stable prices because they are not easily traded between buyers. There are no futures markets for fruits and vegetables by which farmers can hedge their crop, or predict prices.

While some fruits and vegetables have effective grading systems (it is, at least, possible to compare apples to apples because both size and color are graded), the entire lack of grading of cabbages makes for a crazy day at the markets. Most vegetable and fruit farmers turn, instead, to private contracts with buyers and distributors.

Cooperative selling, pick your own services, agrotourism all drive up demand

Other recent innovations to reduce the risks of market variability have been to organize cooperative selling so that if one farmer has misfortune, they are stabilized by their confederates. Some farmers sell pick-your-own services, or undertake the extravagance of tourism, combining the services of a bed and breakfast, educational center or circus with their farming. Some farmers grow both small grains and vegetables, taking the risk that they will earn more on the vegetables but loving the low-risk of the grains.

But this doesn't serve to drive up demand, and in the end the distaste many consumers have these days with fruits and vegetables is not helping those farmers struggling to survive against price variability.

There is typically low demand for fruits and vegetables

Consumers rarely buy enough fruits and vegetables to sustain life.

Recently this has come to concern the United States and other governments. The United States Centers for Disease Control reports in their *Fruit and Vegetable Consumption Among Adults - United States, 2005* reports that 28.7% of men and 36.4% of women eat two or more servings of fruits and vegetables per day. Put another way, two out of every three Americans eat one or less servings of fruits and vegetables per day. This is especially shocking when it is recommended that moderately active men and women eat five to nine servings of fruits and vegetables per day.

Not shockingly, this malnutrition is leading to many diseases. This has been an ongoing problem in America, and data has been kept since the 1930's to assess progress in combating it as the US Department of Agriculture, the Centers for Disease Control and many public and private health advocacies are working to promote the consumption of fruits and vegetables.

Americans are dying for lack of fruits and vegetables, but their ancestors developed the poor eating habits they suffer by.

Demand statistics

What are Americans buying? Research from Jane Reed, Elizabeth Frazão, and Rachel Itskowitz (*How Much Do Americans Pay for Fruits and Vegetables?* USDA, 2004) and Biing-Hwan Lin, Jane Reed and Gary Lucier (*U.S. Fruit and Vegetable Consumption: Who, What, Where, and How Much*, USDA ERS, 2004) indicates many interesting facts.

Preferences for fruits and vegetables vary by age

- Seniors eat fewer French fries and potato chips than toddlers; however, seniors eat more fresh and canned potatoes than younger consumers.
- Toddlers also like to eat apples, fresh as well as processed, whereas adults age 20-59 eat the fewest apples.
- Women 40 and older eat the most spinach, while teenage girls eat the least.

Household income affects consumption of most fruits and vegetables

- High-income consumers drink more orange juice, while low-income consumers drink more orange drinks (less than 10 percent juice).
- Consumption of French fries does not vary by income.
- Compared with low-income consumers, high-income consumers eat more of many vegetables, including fresh celery, garlic, cucumbers, bell peppers, mushrooms, and tomatoes.

The at-home market dominates most fruit and vegetable consumption, except—

- 88% percent of French fries are eaten away from home; fast-food establishments account for 67%
- About 60% of catsup is consumed away from home, and fast-food establishments account for one-third.

Distinct racial/ethnic preferences exist for fruits and vegetables

- Black consumers, though just 13 percent of the U.S. population, account for 21 percent of sweet potato consumption. Puerto Rican Hispanics consume as many sweet potatoes as Black consumers.
- White and Hispanic consumers eat more bell peppers than Blacks and Asians. Blacks eat one-third less per capita than others.
- Per capita spinach consumption is highest among Asians.
- Asians like to eat mushrooms. Blacks eat only one-third as much as Asians per capita.
- Hispanics consume three times more dry beans per capita than the national average.

Regional variations are also evident among some vegetables

- Consumers in the South eat more fresh cabbage than consumers in other regions. As for sauerkraut, three fourths was eaten in the Midwest and East.
- Watermelon consumption is greatest in the West.

Vegetable consumption varies by where consumers live

- Consumers in suburban and rural areas eat about 40 percent fewer fresh snap beans than those living in cities.
- Suburban consumers eat more cucumbers than other consumers do.

Fruits and vegetables are consumed in a variety of ways

- Consumers purchase sweet corn as fresh, frozen, or canned, in nearly equal proportions.
- Processed tomato products account for 80 percent of total tomato consumption. The largest processed use of tomatoes is for sauces, followed by tomato paste, canned whole tomato products, and catsup and juice.

Impact of price on demand is small or nothing

The USDA undertook rigorous analysis of consumer costs to see if it impacted consumption, looking at 57 fruits and vegetables. "We ranked the 27 fruits and 30 vegetables in our sample according to quantity purchased, expenditures, and total servings purchased, regardless of the form in which they were purchased (fresh, canned, frozen, or juice). Again, totals include only the processed products that are plain, unflavored, and/or unsweetened (to the extent possible). Among the 27 fruits, Americans spent the most money on oranges, bought the most pounds of bananas, and ate the most servings of apples. These three fruits were the top three in quantity and servings, and among the top four in expenditures (consumers spent more on grapes than apples). For most fruits (except for watermelon and plums), quantity, cost, and servings are closely related. Among the 30 vegetables, potatoes accounted for the largest share of expenditures, pounds purchased, and servings eaten (table 4). Potato totals were more than three times as many pounds purchased, and nearly four times as many servings (but only 15 percent more dollars) as tomatoes, the second most popular vegetable in all three categories."

Fruits and vegetables are affordable but un-demanded

Disturbingly, the researchers found that price was not keeping consumers from eating their fruits and vegetables: their preferences were. "Even though fresh fruits and vegetables are generally cheaper to eat than processed, for many fruits and vegetables the difference in price per serving between the cheapest and most expensive forms was often less than 25 cents [an amount too small to matter]. For some, this price difference may be a small price to pay for the conveniences—such as longer shelf life, ease of preparation, and greater availability—associated with processed forms. Although the prices for fruits and vegetables in this study are national averages for the entire year and not the prices that any household might face on a given day, they amply demonstrate that cost need not be a barrier to consumption of the recommended amounts of fruits and vegetables. Economic literature suggests that consumers do not respond strongly to changes in prices of fruits

and vegetables (Huang, 1993; Huang and Lin, 2000). However, it is clear that consumers buy more of the lower priced items. Among the 154 forms of fruits and vegetables included in the study, 27% (41 forms) cost less than the weighted-average price per pound, yet they accounted for 60% of total sales volume and 41% of total expenditures."

The farmer need not worry that the fruits and vegetables they sell are unaffordable.

Reasons for low demand include cultural dietary norms, not physiological needs: these norms are shaped by biological impulses designed to react against perceived food scarcity by hungering for high-calorie foods – fruits and vegetables are low calorie foods

It is astounding that consumers can easily afford fruits and vegetables, which they require them for health, and do not buy them.

What is the foundation of this preference against fruits and vegetables? Speculation must take over at this point, fueled by the data of these excellent researchers:

"Longer shelf life" may mean that the fresh produce will not be consumed before it spoils, either because they cannot replace the fruits and vegetables quickly (they cannot get to the supermarket to buy them frequently) or because they are simply not consuming enough to make replacing the fruits and vegetables frequently worthwhile.

"Ease of preparation" may mean that the consumer cannot cook (due to time, lack of skill, or any other factor).

"Greater availability" may mean that seasonal foods leave consumers wanting in the winter, though with greenhouse production and the affordable transportation of fruits and vegetables from tropical and southern nations, this is unlikely. What is more likely is that they simply cannot buy fruits and vegetables at their supermarket because the supermarket does not carry them. This we conclude after visiting supermarkets in our and other areas: as farmers, we must always look at how people buy food. Few supermarkets are blessed with a large produce section, and in many cities, the places where people buy food most frequently do not carry any fruits or vegetables. Programs to encourage stores to carry fruits and vegetables require subsidization to the store owner to compensate for the spoilage!

But, even when vegetables and fruits are available, already prepared and fresh in an affordable way, buying habits remain what they have always been. There is another factor involved, and while these three obstacles to consumption do exist, a primary objection must be met before these three obstacles can be overcome.

We will discuss the three obstacles, and then discover the primary objection is what makes all three obstacles related.

On October 30th, 2009, the *New York Times* reported that convenience stores are the primary source of food in areas where supermarkets do not service, and that these stores do not provide fruits or vegetables. City officials in Newark, New Jersey are subsidizing the provision of fruits and vegetables at these family-owned markets. Cleveland, New York and other cities are undertaking similar efforts. Other cities are providing subsidies to supermarkets to open in underserved areas. "Last year, The American Journal of Epidemiology reported that people with no supermarket near their homes were up to 46 percent less likely to have a healthy diet than those with more shopping options," reports the *Times*.

Yet the reason why these stores do not sell the fresh fruits and vegetables is clear: no vendor will provide something they cannot sell at a profit. Unlike canned fruits or vegetables, fresh product spoils if not bought. And Americans are not buying fresh – or many preserved – fruits and vegetables.

We undertake surveys of local supermarkets and all our competitors several times per year to understand their prices and quality, so we can better understand our competitiveness. It is a good habit of a successful farmer and an excellent chance to learn. We have gained employment with some of these competitors to better learn their operational procedures. Universally we have found that in supermarkets, where the majority of Americans buy their food, fruit and vegetables are allowed to rot on the shelves, and are put out on the shelves in unripened states that are distasteful, to say the least. Unripened fruits and vegetables stay unspoiled longer than ripe fruits and vegetables.

Usually, the fruits and vegetables come in a damaged state, and the decay and damage has become normalized and accepted by consumers who have not learned by alternatives to expect better. Often they are left on the shelf until enough have sold because the store does not wish to lose money on the produce. At one store, whose store manager spoke with us on the condition of remaining anonymous, the store expected to lose money on the produce and used it only to "get people in the door. People come here and if they don't see fruits and vegetables – even if they don't buy them – they will go somewhere else because it doesn't feel like a supermarket to them. I have become a candyman, I sell chips and soda. I sell almost no produce. These people like to look at the fruits and vegetables and buy chips, soda and candy."

In restaurants, another major source of consumption in America, fruits and vegetables are received in spoiled and unripe condition: discerning chefs in our region, we found by interview, could not use (on average) 25% to 100% of the fruits or vegetables they bought, and were forced to either radically alter their menu to present potatoes and other hard-to-spoil items, or accept the lower quality food.

If they do end up throwing out the food, they cannot be refunded and the food costs more and their customers go elsewhere. Thankfully, as one Thai Cuisine chef explained to us on the condition of remaining anonymous, her customers "can't tell the difference between ripe and unripe."

It is astounding that consumption of fruits and vegetables has decreased to the point that there is disease of malnutrition in America. Yet this is, perhaps, cause to hope that consumers will "come back" to fruits and vegetables, driving up prices...

But they will not come back until farmers can provide to them fruits and vegetables fresh and unspoiled, at prices they can afford, and all year long.

But even then they will not likely come back: American buying habits are, as examined by the USDA, definitely anti-fruit and anti-vegetable. Children grow up not eating fruits and vegetables until their doctors prescribe them to cure disease, and then, these children (now adults) find produce that is rotten and unripe at the same time, and cannot get their children to eat the fruits and vegetables.

One visitor to our farm brought her children, and was astounded that her daughters and son were eating radishes, spinach and green beans. We asked her children why they did not eat vegetables at home. The answer was anonymous: "they taste bad at home, they're squishy and mushy at home." The mother was not pleased, as she thought she was buying quality foods. However, her children knew better that vegetables should not be squishy, mushy and foul-tasting. Children have not learned to tolerate rotten foods and will choose foods that are not rotten and not

healthful over those that are rotten and possibly healthful. Many of our animals will make the same decision in trials we undertook afterwards to learn more about this phenomenon.

Methods by which demand can be increased: address physiological needs; examples of the failure of marketing campaigns to teach people how to cook and eat healthy foods. Introduction of biological instincts against fruit and vegetable consumption: food insecurity (which is different from overt hunger, and triggers a biological response to build up caloric energy in case of lack of food), high energy foods trigger pleasure responses, and the influence of parents on children.

There are two obvious solutions, but neither address the primary objection to fruits and vegetables: the farmer can try to please their local demand or they can try to demonstrate need for fruits and vegetables. We will discuss these before introducing a more functional third option.

Pleasing local demand has its limitations. Until the situation changes radically, the farmer can examine their regional and ethnic / racial neighborhood and what is consumed widely there for guidance. If possible, the spinach farmer should relocate to a region populated by wealthy Asians while the bean and pepper farmer would do well to relocate among Hispanics; the farmer who finds themselves near a Black and Puerto Rican community should plant sweet potatoes.

Demonstrating need for fruits and vegetables is also a dubious and quixotic strategy. Yet, each farmer can undertake efforts – with the USDA, the CDC and the neighborhood physician – to encourage Americans to change their eating habits to include those foods easily grown nearby, and many fruits and vegetables.

We have tried both of these. We had more success trying to please local demand than by demonstrating need. In promoting fruits and vegetables, we have found that our most effective way of increasing demand is to sell a great variety of fruits and vegetables. If the consumer can also have the option of buying eggs, honey and other animal products with their fruits and vegetables, they will buy more. Because consumers dislike shopping for food, consumers want to limit their shopping for food to one vendor, and the farmer must become their supermarket.

To do this, the farmer must cooperatively work with other farmers: it is impossible that the farmer can be so well diversified as to provide all that a supermarket can! Yet, little by little, a farm can diversify its production and rely on confederates and cooperative neighbors less and less.

Yet, little by little, the farm becomes something very different than a simple agricultural operation.

Not only must the farmer be a supermarket, they must also be a chef. Consumers are spending less time cooking. The *New York Times* reports in *Out of the Kitchen, Onto the Couch* (Michael Pollan, July 29, 2009) that "Today the average American spends a mere 27 minutes a day on food preparation (another four minutes cleaning up); that's less than half the time that we spent cooking and cleaning up when Julia [Childs] arrived on our television screens [in her television cooking show, *The French Chef*, 1963]. It's also less than half the time it takes to watch a single episode of "Top Chef" or "Chopped" or "The Next Food Network Star." [Contemporary television shows on cooking] What this suggests is that a great many Americans are spending considerably more time watching images of cooking on television than they are cooking themselves — an increasingly archaic activity they will tell you they no longer have the time for."

Pollan continues. "Curiously, the year Julia Child went on the air — 1963 — was the same year Betty Friedan published *The Feminine Mystique*, the book that taught millions of American women

to regard housework, cooking included, as drudgery, indeed as a form of oppression. You may think of these two figures as antagonists, but that wouldn't be quite right. They actually had a great deal in common, as Child's biographer, Laura Shapiro, points out, and addressed the aspirations of many of the same women. Julia never referred to her viewers as 'housewives' — a word she detested — and never condescended to them. She tried to show the sort of women who read *The Feminine Mystique* that, far from oppressing them, the work of cooking approached in the proper spirit offered a kind of fulfillment and deserved an intelligent woman's attention. (A man's too.) Second-wave feminists were often ambivalent on the gender politics of cooking. Simone de Beauvoir wrote in *The Second Sex* that though cooking could be oppressive, it could also be a form of 'revelation and creation; and a woman can find special satisfaction in a successful cake or a flaky pastry, for not everyone can do it: one must have the gift.' This can be read either as a special Frenchie exemption for the culinary arts (féminisme, c'est bon, but we must not jeopardize those flaky pastries!) or as a bit of wisdom that some American feminists thoughtlessly trampled in their rush to get women out of the kitchen."

Americans are not buying fruits and vegetables and fruits because they cannot cook? Certainly not. Restaurants, prepared foods and other sources of edibles that require no cooking could use extensive quantities of vegetables and fruits. No, the necessary clue, the an insight into the behavior of the consumer lies in their lack of demand, either for their own cooking or in the cooking of others: the behavior that would reduce necessary fruits and vegetables in the diet to the point of malnutrition is the same suicidal behavior that would not take the time to cook a nutritious, delicious, desired and affordable meal when an innutritious, disgusting, undesired and expensive alternative presents itself.

Pollan's hypothesis (that Americans do not cook because they have no time) is typical, but holds little weight. When Julia Childs, arguably one of the greatest culinary teachers of all time, set herself the task of teaching Americans how to cook, it was because Americans had forgotten how to cook. Though Pollan does not pursue the story of this original sin (such history rarely belongs in a periodical newspaper), he manages to discover just what consumers are looking for from their food providers, and why. For those who do not have ready access to the archives of the New York Times, or are unfamiliar with the typical understanding of why consumers do not buy fruits and vegetables, we have reprinted here the significant portions of Pollan's article:

I spent an enlightening if somewhat depressing hour on the phone with a veteran food-marketing researcher, Harry Balzer, who explained that "people call things 'cooking' today that would roll their grandmother in her grave — heating up a can of soup or microwaving a frozen pizza." Balzer has been studying American eating habits since 1978; the NPD Group, the firm he works for, collects data from a pool of 2,000 food diaries to track American eating habits. Years ago Balzer noticed that the definition of cooking held by his respondents had grown so broad as to be meaningless, so the firm tightened up the meaning of "to cook" at least slightly to capture what was really going on in American kitchens. To cook from scratch, they decreed, means to prepare a main dish that requires some degree of "assembly of elements." So microwaving a pizza doesn't count as cooking, though washing a head of lettuce and pouring bottled dressing over it does. Under this dispensation, you're also cooking when you spread mayonnaise on a slice of bread and pile on some cold cuts or a hamburger patty. (Currently the most popular meal in America, at both lunch and dinner, is a sandwich; the No. 1 accompanying beverage is a soda.) At least by Balzer's none-too-exacting standard, Americans are still cooking up a storm — 58 percent of our evening meals qualify, though even that figure has been falling steadily since the 1980s.

Like most people who study consumer behavior, Balzer has developed a somewhat cynical view of human nature, which his research suggests is ever driven by the quest to save time or money or, optimally, both. I kept asking him what his research had to say about the prevalence of the activity I referred to as "real scratch cooking," but he wouldn't touch the term. Why? Apparently the activity has become so rarefied as to elude his tools of measurement.

"Here's an analogy," Balzer said. "A hundred years ago, chicken for dinner meant going out and catching, killing, plucking and gutting a chicken. Do you know anybody who still does that? It would be considered crazy! Well, that's exactly how cooking will seem to your grandchildren: something people used to do when they had no other choice. Get over it."

Pollan discovers that cooking shows are now entertainment rather than education, and that eating is a pastime and hobby instead of something basically essential to keeping a family ready for work and harmonious.

But the shift from producing food on television to consuming it strikes me as a far-less-salubrious development. Traditionally, the recipe for the typical dump-and-stir program comprises about 80 percent cooking followed by 20 percent eating, but in prime time you now find a raft of shows that flip that ratio on its head, like "The Best Thing I Ever Ate" and "Diners, Drive-Ins and Dives," which are about nothing but eating. Sure, Guy Fieri, the tattooed and spiky-coiffed chowhound who hosts "Diners, Drive-Ins and Dives," ducks into the kitchen whenever he visits one of these roadside joints to do a little speed-bonding with the startled short-order cooks in back, but most of the time he's wrapping his mouth around their supersize creations: a 16-ounce Oh Gawd! burger (with the works); battered and deep-fried anything (clams, pickles, cinnamon buns, stuffed peppers, you name it); or a buttermilk burrito approximately the size of his head, stuffed with bacon, eggs and cheese. What Fieri's critical vocabulary lacks in analytical rigor, it more than makes up for in tailgate enthusiasm: "Man, oh man, now this is what I'm talkin' about!" What can possibly be the appeal of watching Guy Fieri bite, masticate and swallow all this chow?

The historical drift of cooking programs — from a genuine interest in producing food yourself to the spectacle of merely consuming it — surely owes a lot to the decline of cooking in our culture, but it also has something to do with the gravitational field that eventually overtakes anything in television's orbit. It's no accident that Julia Child appeared on public television — or educational television, as it used to be called. On a commercial network, a program that actually inspired viewers to get off the couch and spend an hour cooking a meal would be a commercial disaster, for it would mean they were turning off the television to do something else. The ads on the Food Network, at least in prime time, strongly suggest its viewers do no such thing: the food-related ads hardly ever hawk kitchen appliances or ingredients (unless you count A.1. steak sauce) but rather push the usual supermarket cart of edible foodlike substances, including Manwich sloppy joe in a can, Special K protein shakes and Ore-Ida frozen French fries, along with fast-casual eateries like Olive Garden and Red Lobster...

...The Food Network has helped to transform cooking from something you do into something you watch — into yet another confection of spectacle and celebrity that keeps us pinned to the couch. The formula is as circular and self-reinforcing as a TV dinner: a simulacrum of home cooking that is sold on TV and designed to be eaten in front of the TV. True, in the case of the Swanson rendition, at least you get something that will fill you up; by comparison, the Food Network leaves you hungry, a condition its advertisers must love. But in neither case is there much risk that you will get off the couch and actually cook a meal. Both kinds of TV dinner plant us exactly where television always wants us: in front of the set, watching....

...If cooking really offers all these satisfactions, then why don't we do more of it? ...for most of us it doesn't pay the rent, and very often our work doesn't leave us the time...For many years now, Americans have been putting in longer hours at work and enjoying less time at home. Since 1967, we've added 167 hours — the equivalent of a month's full-time labor — to the total amount of time we spend at work each year, and in households where both parents work, the figure is more like 400 hours. Americans today spend more time working than people in any other industrialized nation — an extra two weeks or more a year. Not surprisingly, in those countries where people still take cooking seriously, they also have more time to devote to it.

It's generally assumed that the entrance of women into the work force is responsible for the collapse of home cooking, but that turns out to be only part of the story. Yes, women with jobs outside the home spend less time cooking — but so do women without jobs. The amount of time spent on food preparation in America has fallen at the same precipitous rate among women who don't work outside the home as it has among women who do: in both cases, a decline of about 40 percent since 1965. (Though for married women who don't have jobs, the amount of time spent cooking remains greater: 58 minutes a day, as compared with 36 for married women who do have jobs.) In general, spending on restaurants or takeout food rises with income. Women with jobs have more money to pay corporations to do their cooking, yet all American women now allow corporations to cook for them when they can.

Those corporations have been trying to persuade Americans to let them do the cooking since long before large numbers of women entered the work force. After World War II, the food industry labored mightily to sell American women on all the processed-food wonders it had invented to feed the troops: canned meals, freeze-dried foods, dehydrated potatoes, powdered orange juice and coffee, instant everything. As Laura Shapiro recounts in "Something From the Oven: Reinventing Dinner in 1950s America," the food industry strived to "persuade millions of Americans to develop a lasting taste for meals that were a lot like field rations." The same process of peacetime conversion that industrialized our farming, giving us synthetic fertilizers made from munitions and new pesticides developed from nerve gas, also industrialized our eating.

Shapiro shows that the shift toward industrial cookery began not in response to a demand from women entering the work force but as a supply-driven phenomenon. In fact, for many years American women, whether they worked or not, resisted processed foods, regarding them as a dereliction of their "moral obligation to cook," something they believed to be a parental responsibility on par with child care. It took years of clever, dedicated marketing to break down this resistance and persuade Americans that opening a can or cooking from a mix really was cooking. Honest. In the 1950s, just-add-water cake mixes languished in the supermarket until the marketers figured out that if you left at least something for the "baker" to do — specifically, crack open an egg — she could take ownership of the cake. Over the years, the food scientists have gotten better and better at simulating real food, keeping it looking attractive and seemingly fresh, and the rapid acceptance of microwave ovens — which went from being in only 8 percent of American households in 1978 to 90 percent today — opened up vast new horizons of home-meal replacement.

Harry Balzer's research suggests that the corporate project of redefining what it means to cook and serve a meal has succeeded beyond the industry's wildest expectations. People think nothing of buying frozen peanut butter-and-jelly sandwiches for their children's lunchboxes. (Now how much of a timesaver can that be?) "We've had a hundred years of packaged foods," Balzer told me, "and now we're going to have a hundred years of packaged meals." Already today, 80 percent of the cost of food eaten in the home goes to someone other than a farmer, which is to say to industrial cooking and packaging and marketing. Balzer is unsentimental about this development: "Do you miss sewing or darning socks? I don't think so."

So what are we doing with the time we save by outsourcing our food preparation to corporations and 16-year-old burger flippers? Working, commuting to work, surfing the Internet and, perhaps most curiously of all, watching other people cook on television...

Again, Pollan comes nearly to the point, but close enough to illuminate through his errors the truth. If Americans were greedy enough with their time and money to avoid spending money and time on something that promotes health, enjoyment and life alone, perhaps his argument's weight would sustain his words. Yet cooking, and cooking fruits and vegetables, improves monetary economy as well. The clue lies in understanding that eating is now a lifestyle choice, a show, a means of escape and impersonation. Eating is a cultural undertaking and fruits and vegetables are definitely "low class" fare.

Hayden Stewart and Noel Blisard of the USDA ERS in their publication *Are Lower Income Households Willing and Able To Budget for Fruits and Vegetables? Economic Research Report No. (ERR-54) 29 pp, January* 2008 discover the shocking truth that the poor would rather afford expensive and unwholesome foods than nutritious and affordable fruits and vegetables for reasons of taste and convenience. Beef and frozen prepared foods are what the poor – and most Americans – desire.

"Households have a number of needs and wants that all compete for scarce resources. Given this situation, are low-income households, in particular, generally willing and able to budget for healthful foods like fruits and vegetables, or are other goods and services, including other foods, more of a priority? For six out of seven selected types of food, we find that households with an income below 130 percent of the poverty line spend less money than higher income households. However, we also find that these households, when given a small increase in income, will allocate more money to only two out of the seven products, beef and frozen prepared foods. These foods may be priorities for reasons of taste and convenience. For additional money to be allocated to fruits and vegetables, a household's income needs to be slightly greater than 130 percent of the poverty line."

Do they desire these foods because of taste and convenience alone? Adam Drewnowski and SE Specter (*Poverty and obesity: the role of energy density and energy costs*, Center for Public Health Nutrition, Departments of Epidemiology and Medicine, University of Washington, Seattle (AD), and the US Department of Agriculture Western Human Nutrition Research Center, University of California, Davis) suggest shocking evidence that consumers are calorie oriented, not health oriented, when making meal decisions:

Many health disparities in the United States are linked to inequalities in education and income. This review focuses on the relation between obesity and diet quality, dietary energy density, and energy costs. Evidence is provided to support the following points. First, the highest rates of obesity occur among population groups with the highest poverty rates and the least education. Second, there is an inverse relation between energy density (MJ/kg) and energy cost ($/MJ), such that energy-dense foods composed of refined grains, added sugars, or fats may represent the lowest-cost option to the consumer. Third, the high energy density and palatability of sweets and fats are associated with higher energy intakes, at least in clinical and laboratory studies. Fourth, poverty and food insecurity are associated with lower food expenditures, low fruit and vegetable consumption, and lower-quality diets. A reduction in diet costs in linear programming models leads to high-fat, energy-dense diets that are similar in composition to those consumed by low-income groups. Such diets are more affordable than are prudent diets based on lean meats, fish, fresh vegetables, and

fruit. The association between poverty and obesity may be mediated, in part, by the low cost of energy-dense foods and may be reinforced by the high palatability of sugar and fat. This economic framework provides an explanation for the observed links between socioeconomic variables and obesity when taste, dietary energy density, and diet costs are used as intervening variables. More and more Americans are becoming overweight and obese while consuming more added sugars and fats and spending a lower percentage of their disposable income on food.

When the objective is to gain calories instead of nutrition, buying decisions follow suit: vegetables and fruits are excellent and affordable sources of necessary nutrition to health, but are poor and expensive sources of calories. The wealthiest members of American society can afford to spend money on expensive sources of calories (affordable sources of nutrition) while the poor must make do with cheaper options for calories.

Both the wealthy and the poor then suffer from dietary disease and malnutrition while enjoying their high-calorie diet.

There are several reasons for this behavior, according to Drewnowski and Specter. One is food insecurity (which is different from overt hunger): this triggers a biological response to build up caloric energy in case of lack of food. Another biological response in play is that high energy foods trigger pleasure responses. A third biological response is in the influence of parents on children.

Teaching how to cook does not increase demand when people still hunger for high-calorie foods. Perceptions of food scarcity are not based in realistic observations: customers must be assured they are wealthy enough to afford low-calorie foods, that their wealth is secure and that the "good times" are going to stay

While the wealthiest and poorest Americans do spend different amounts per person on food, the difference as found by the Department of Agriculture (Kaufman PR, MacDonald JM, Lutz SM, Smallwood DM. *Do the poor pay more for food? Item selection and price differences affect low-income household food costs*. 1997. Report 759) was minimal: "In 1992, households in the top quintile by income (mean income: US$77 311/y) spent US$1997/person (2.6% of total expenditures) for food, compared with US$1249 (18.7%) spent by those in the bottom quintile (mean income: US$6669/y). Wealthier households bought higher-quality meats, more fish and seafood, more fruit and vegetables, and more convenience foods. Despite buying lower-cost items, poor households devoted a far greater share of their disposable income to food. Their level of satisfaction with the perceived quality of the diet was not reported" (Drewnowski and Specter).

This difference amounts to $14.38 per week, and with 2 meals per day, this amounts to a difference of $1.03 per meal. The poor eat poorly because they are afraid of not getting another meal and must obtain excess calories, whereas the rich eat richly because they are confident in the next meal and may indulge in nutrition.

Besides biological responses to perceived food insecurity, cultural influences also are at play. These are harder to quantify, and while biological responses may be a primary factor in low demand for fruits and vegetables, there is little way of knowing how important these cultural factors are.

Since we began selling beans, some Hispanic families would not buy beans from us because it was "poor Mexican food" and they were "now rich Americans." They wanted to eat meals prepared by someone else every day, and vegetables on their plate were abhorrent because it reminded these immigrants and grandchildren of immigrants of a heritage they want to leave behind.

These sons and daughters and great-grandsons and great-granddaughters of immigrants use their meals as diversion, entertainment, delusion. To some of them who would talk to us about it, and likely to those who would not, fruits and vegetables, being affordable and necessary to health, are the food of the poor who cannot afford doctors and hospitals, who cannot afford processed foods. Those who cook do so because they cannot afford anyone else to do it for them.

Curious, we investigated and found this sentiment among our White, Black and Asian ethic customers as well.

The spurning of these foods by the poor is ironic, in times of poverty and weakness, healthful fruits, vegetables, whole grains, eggs, and dairy have helped people grow strong enough to gain wealth.

The poor and weak naturally attempt to emulate the strong and wealthy: writing of the English in his *Natural Diet of Man* (1923, page 290), Dr. John Kellogg describes the phenomenon: "in the fourteenth century, the common people ate little besides bread, butter, cheese, and vegetables. It is interesting to note that the English names of meats are of Norman origin, while the names of vegetables are all Saxon [a "cow" to a Saxon was a "beef" to a Norman. The difference remains in modern English and French]. The leek appears to have been the principle vegetable among the Anglo-Saxons. Garden cresses and other herbs were in use. The chief fruit was the apple. Nuts and plums were grown, and the small kernels of the pine were very extensively used. Cherries were very popular in the Middle Ages." After the Norman conquest, Kellogg explains, meat became defined as a good consumed by the wealthy nobility and desired by the poor commons. By the time that Jethro Tull was able to reduce the price of meat to such that even the poorest of the English could afford, the desire was rooted and ready to be fed. More, the understanding of fruits and vegetables as the food of the common poor was rooted and the people were ready to be starved.

In all cultures, meat is understood as the food of prosperity, of the "good times," of the wealthy and the nobility. There is, in fact, in America a hamburger chain by the name of "good times burgers," and President Franklin Roosevelt's desire to ensure a "chicken in every pot" won him the admiration as an equalizer between wealthy and poor. Meat is too expensive a food for farmers: the cow that is slaughtered would give good milk, the chicken would give good eggs; animals raised for meat requires the indulgence of the wealthy, and though Tull's genius allows for even the poor to afford meat, it does not encourage the poor to continue eating vegetables and fruits, or even to cook for themselves.

The affordability of meat creates a situation where a bonus earned by alfalfa farmers encourages them to feed cattle with hay instead of the poor with bread.

Trying to convince consumers that vegetables and fruits are luxury foods works only so well, and while magnificent prices can be earned by the experimental farmer in pricing games to make the food appear as luxurious as the hamburger currently hungered for, it is not a profitable game. We undertook such an experiment and earned $40 per zucchini for a half-dozen zucchinis, and $25 for a pound of potatoes for more than 10 individual pounds of potatoes. Yet we did not sell enough zucchinis or potatoes at this price to convince us against charging a more normal price for them: charging less we sell more, and we make up the difference in volume.

No, no arguments will sway the consumer: it seems nothing will sway them from their desire for wealth, power and nobility, their desire for servants to cook for them, their desire for sickness so they might show they can afford to pay for doctors. They wish to show that they have no fear for the future, they can live large and pay the price. It is possible studies that show the dangers of avoiding fruits and vegetables might even inflame their desire to eat poorly.

Because Pollan and others whose viewpoint he shares do not take the time to understand, they are confused and cannot comprehend the suicidal tendencies of his fellow Americans:

... Consider some recent research on the links between cooking and dietary health. A 2003 study by a group of Harvard economists led by David Cutler found that the rise of food preparation outside the home could explain most of the increase in obesity in America. Mass production has driven down the cost of many foods, not only in terms of price but also in the amount of time required to obtain them. The French fry did not become the most popular "vegetable" in America until industry relieved us of the considerable effort needed to prepare French fries ourselves. Similarly, the mass production of cream-filled cakes, fried chicken wings and taquitos, exotically flavored chips or cheesy puffs of refined flour, has transformed all these hard-to-make-at-home foods into the sort of everyday fare you can pick up at the gas station on a whim and for less than a dollar. The fact that we no longer have to plan or even wait to enjoy these items, as we would if we were making them ourselves, makes us that much more likely to indulge impulsively.

Cutler and his colleagues demonstrate that as the "time cost" of food preparation has fallen, calorie consumption has gone up, particularly consumption of the sort of snack and convenience foods that are typically cooked outside the home. They found that when we don't have to cook meals, we eat more of them: as the amount of time Americans spend cooking has dropped by about half, the number of meals Americans eat in a day has climbed; since 1977, we've added approximately half a meal to our daily intake.

Cutler and his colleagues also surveyed cooking patterns across several cultures and found that obesity rates are inversely correlated with the amount of time spent on food preparation. The more time a nation devotes to food preparation at home, the lower its rate of obesity. In fact, the amount of time spent cooking predicts obesity rates more reliably than female participation in the labor force or income. Other research supports the idea that cooking is a better predictor of a healthful diet than social class: a 1992 study in The Journal of the American Dietetic Association found that poor women who routinely cooked were more likely to eat a more healthful diet than well-to-do women who did not.

So cooking matters — a lot. Which when you think about it, should come as no surprise. When we let corporations do the cooking, they're bound to go heavy on sugar, fat and salt; these are three tastes we're hard-wired to like, which happen to be dirt cheap to add and do a good job masking the shortcomings of processed food. And if you make special-occasion foods cheap and easy enough to eat every day, we will eat them every day. The time and work involved in cooking, as well as the delay in gratification built into the process, served as an important check on our appetite. Now that check is gone, and we're struggling to deal with the consequences...

...it's hard to imagine ever reforming the American way of eating or, for that matter, the American food system unless millions of Americans — women and men — are willing to make cooking a part of daily life. The path to a diet of fresher, unprocessed food, not to mention to a revitalized local-food economy, passes straight through the home kitchen.

But if this is a dream you find appealing, you might not want to call Harry Balzer right away to discuss it.

"Not going to happen," he told me. "Why? Because we're basically cheap and lazy. And besides, the skills are already lost. Who is going to teach the next generation to cook? I don't see it.

"We're all looking for someone else to cook for us. The next American cook is going to be the supermarket. Takeout from the supermarket, that's the future. All we need now is the drive-through supermarket."

Crusty as a fresh baguette, Harry Balzer insists on dealing with the world, and human nature, as it really is, or at least as he finds it in the survey data he has spent the past three decades poring over. But for a brief moment, I was able to engage him in the project of imagining a slightly different reality. This took a little doing. Many of his clients — which include many of the big chain restaurants and food manufacturers — profit handsomely from the decline and fall

of cooking in America; indeed, their marketing has contributed to it. Yet Balzer himself made it clear that he recognizes all that the decline of everyday cooking has cost us.

Selling fruits and vegetables is more difficult than selling hay: the farmer must sell hope and joy. This problem has been existent since Tull's First Edition.

It is complicated to sell vegetables and easy to sell hay: the conflicted insanity of the customer in the face of various biological and cultural pressures brings them to suicide, and to save them the farmer must confront these demons with hope.

To inspire this hope is difficult. Consumers care about the way the food was grown not for the impact on flavor (which, as our Thai friend explained, they can no longer notice), but their self-image. They want to know it was grown without manure not because it tastes better or is safer, but because then eating that food is an act of self-expression. They must be able to change their self-perception by buying fruits and vegetables, they must be able to reflect how confident they are as they eat.

The problem existed in Tull's time, when the wealthy would pay for dunged wine, and the poor would desire what their nobles preferred. Tull says, "dung spoils the fine flavor of our food. The dunged vineyards of Languedoc produce nauseous wine and a proverb in that country: "poor people's wine is best because they carry no dung to their vineyards."

The farmer must undertake extensive advertising and image shopping. They must have websites and phone numbers – their customers don't want to talk to the farmer, they want to talk to the farmer's servants and wish to think that their farmer is serving so many other people that they can afford such servants. Americans want service because it is social status. They can be made to feel wealthy and affluent.

It is little wonder that only the bravest farmers dare to grow fruits and vegetables!

Likely, the farmer will not undertake vegetable and fruit production to sell – it is too much work – but for the consumption of their own family and workers. Healthy workers work harder; vegetables and fruits improve not only health, but affluence as well. Fresh food has more nutrition than old food, and is much cheaper: let the farmer earn the savings from their seed, they do not need to pay for fancy marketing from other farmers.

But, should the farmer try to sell fruits and vegetables, they must grow a supermarket's selection of food, and then prepare satisfying, nutritional and, above all else, expressive, luxurious, secure, self-image changing meals for their customers. For this, some farmers partner with chefs. Most farmers give up and sell to restaurants or distributors who sell to restaurants, who can better cater to the experiential dining that consumers desire.

Specific strategies: farmers encouraged to specialize and contract for cooperation to provide maximum diversity of products for minimal cost

Due to these market conditions, farmers are encouraged to specialize and work together to provide the demand for a varied diet, with some farmers specializing in the sale of the fruits and vegetables especially. With one farmer growing beans and another growing leafy greens, a third farmer who has contracted for the sale of both beans and greens can contract for their production.

This is a vital strategy for those farmers who do not have the resources to enjoy the economies of scale necessary to meet the very low market prices and in this method of contracted cooperation, a farmer of even 1/10 of an acre can provide everything from beef and eggs to beans and lettuce and focus on those products that require intensive technical skill and attention, those products that spoil quickly, or those products which are uneconomical to ship even medium distances (such as mushrooms, sprouts, honey, dried fruit – even if it is the drying of contracted fruit, etc.). Thus armed with contracted cooperation, any farmer can provide the one-stop-shop so demanded by their customers.

Through specialization and contracts with other specialized farms, each farmer is able to concentrate on those products which they grow best and provide to their customers the maximum diversity of products for minimal cost.

In the contract, the farmer may require various qualities demanded by their customers to increase demand, such as no herbicide, pesticide or fertilizer, or even management practices such as Tullian farming. However, with the numerous farmers providing to the market, it is not unreasonable to suppose that there might be at least one farmer to contract with that does not provide food already of the qualities demanded and these should be contracted with first as no surcharge will be required for alterations to their standard production procedures.

Because so many customers want a variety of products but a consistent volume of them every week, it makes sense to sell in boxes. These boxes can be of any size the farmer and customer desire and offering various sizes will show the farmer what size boxes are most demanded. Price the smallest boxes most expensive per volume, and the largest ones least expensive per volume to encourage the customer to buy more. Do not discount from the highest price per volume, but price your profit margin based on the price of your least price per volume: this way, if a customer is enticed to buy the maximum volume, you obtain your minimum desired profit margin. In example, the largest volume might cost $1.00 per volume and offer the farmer a margin of 33% profit, and the smallest volume might cost $1.12 per volume and offer the farmer a margin of 42.6% profit, presenting to the customer a savings of 12% if they buy more. Gallons are a convenient volume for many customers. Though an adult human ought to eat about a bushel of fruits and vegetables alone, and eats many bushels of food per week, it is unreasonable to expect that the customer will want all or even most of their food from your farm, and offering boxes as small as 2 to 3 gallons may be just right for your market. Do not make your boxes too small, or else the customer will be dissatisfied they are buying so little: you must figure out what size they are expecting and provide that as the minimum size box available.

The boxes should be overfilled by 25% to increase customer satisfaction. If they are buying 4 gallons, give them 5. This does not mean you will lose money: price the 4 gallon box as if it were 5 gallons.

Provide free samples of premium products every week: giving away a free $1 melon will result in customer retention and satisfaction, translating into dozens or hundreds of more dollars during the consumer's patronage.

Everything in the box should be the same price because the consumer is wanting a specific volume and a great diversity: this will increase satisfaction. Measure the price per volume of all your products and establish the price per volume at just over half the average price per volume. For premium products (like honey comb) or products that are volumetrically dense (like eggs), establish a slightly lower volumetric value either through packaging (such as cartons or boxes), or by specifically establishing that 12 eggs are equivalent to a particular volume. For example, if each gallon is worth $1 and you want your eggs to be worth $0.25 each, inform your customers that each

dozen eggs is the equivalent of 3 gallons. While technically this sets the price of eggs higher than other products in the box, the consumer still is thinking in terms of volume because that is what they want to purchase: variety with volume. While you think of eggs as a per-each cost, your customer is thinking per gallon, and it is important to translate all terms appropriately, and to ensure that every gallon is priced the same.

Pricing should also provide discounts for frequency. If a customer agrees to contract for the purchase of a set quantity of boxes (say, 5 or 10 boxes), offer an increasing discount for the number of boxes: say, 12% for 5 boxes, and 25% for 10. Of course, establish your minimum margin for the maximum quantity. Offer as your maximum quantity 52 boxes: one per week during the year: unlike most other farmers, you can provide food year-long, if not through your own efforts of growing produce in the winter, than through the contracting of exotic foods (such as tropical and subtropical fruits, nuts, vegetables and fruits) and the sale of preserved items (dry beans, grains, dried fruits, jellies, honey, etc.).

Because customers will demand some products more than others, contract for a particular quantity of gallons during the season. This way, they can fill their gallons with what they want when it is in season. Divide the payments due for the year's worth of boxes into monthly installments to make it easier for them to afford and you will get a steady income. This may be inconvenient to you: your customers may all want lots of produce mid-summer and none in the winter, but this has not been the case in our experience: some customers prefer winter foods, others prefer summer foods, and providing a variety of fresh foods year-long (especially in winter, providing mushrooms, sprouts, dry beans, grains, eggs, etc.) and establishing reasonable prices so that at any given time of the year a box still costs you the same per volume will keep everyone happy.

Establishing discounts for quantity and frequency might allow a customer to save 50% (25% for frequency + 25% for quantity), but can also allow the farmer a bonus for the individualized care that such small boxes usually require. Small customers require more attention than large customers: not one item in the box may be damaged, everything must be perfect because the error will be magnified greatly due to its relativity to the size of the box: 1 bruised tomato in a bushel is no big deal and is acceptable, but 1 tomato out of 3 is very bad and is unacceptable and such small boxes require extraordinary packaging and handling.

While the farmer can and should deliver even large orders without any damage (even though customers who buy large quantities do so for the discount, and may expect to discard even 25% of the produce), the cost of time in customer service is equivalent between small and large orders and the farmer would lose money on small orders that simply do not pay for their time in customer service if not for that large margin. Combined with the requirement for greater packaging, this greater per-customer service earns the large margin.

The farmer who teaches gardening lessons also increases their customer base and provides necessary services to the community. Without condescending to agrotainment and carnivals, the farmer can respectfully earn additional income to their production through such services. Charging per hour per student in small or medium-large classes can earn as much per customer as any box usually sold, and the cost of tuition should be similar: the intensive hour of customer service that teaching requires costs the farmer the same amount as an intensive hour of customer service to box-customers. That said, if well done, many of their students will purchase one or two or more boxes of produce when at the farm, and later when they arrive home.

Allow customers to try before they buy. Not only free samples, but if they purchase a single box, apply that purchase to a larger contract so that they can more freely transition from a single box into a dozen or more.

In advertising, employ the use of different colors, fonts and sizes to bring attention to the most important information: the type of product, its price and how to buy it (your contact information). To do this, employ the study of pointillist art by dividing the advertisement into clearly defined sections using bolder and larger font as "lines."

Employ psychology: cool colors, especially blue and green, are easier to remember and also encourage a willingness to buy. E and I sounds encourage a willingness to buy more than O, OO and U sounds. Prices that use round numbers, in units of 5 or 10, are easier to understand and remember.

Do the math for your customer: if you offer savings for larger or more frequent purchases, tell them by percentage how much they save. Tell them how much each unit costs. Require as little thinking of them as possible. Color-code and font-code information on your advertisement so that information regarding the product, regarding the price, regarding savings, and other information are each of similar font and color. If color is unavailable as an option, make good use of various fonts.

If possible, include a picture or illustration of the product, but do not offer more than one or two illustrations per advertisement so that the reader is not overwhelmed by it. Use the picture to help them associate what they are reading with an image.

Summary of suggestions

Thus,

- The farmer must be a chef, the farm must be a show.
- Marketing food directly to consumers means selling the image of the food, the image of luxury.
- Farmers must make the customer feel like they can always afford food, that they don't need to flex their economic muscle to demonstrate their strength.
- The farmer must be like an artist seeking a patron, a sponsor: they must demonstrate to the wealthy and powerful, and the poor who wish they were wealthy and powerful, that by buying food – prepared food – from their farm, they are obtaining a loyal servant, an ownership of the farm, and undertaking good deeds worth boasting about over dinner with friends... a dinner which, likely, will be prepared and eaten at a restaurant while the farm fresh food spoils in the refrigerator.
- If you at all doubt your courage or ability, do not grow fruits or vegetables. It is the toughest market in the world: three biological instincts of your customers drive them to suicide, and your vitally important, easily affordable products will likely rot on your fields before they are eaten by those whose lives they would save unless you can help your pitable customers find reasons to hope they might live.
- That said, if you were born a hero, then try your luck: you can make a fortune because the stakes are high.

Examples of macabre fruit and vegetable farmer humor: basing farm decisions on anticipated production when demand cannot be accurately anticipated or effectively increased; the uselessness of yield estimates for fruits and vegetables

With the situation as it is and few farmers understanding why demand for fruits and vegetables are low, there is a macabre humor about fruit and vegetable farming that does not exist

for grain farmers. Even some seed growers are not aware of the situation and still try to help farmers estimate the yield so they can at least make informed decisions based on current prices on what to grow...even though a bushel of beans may or may not be worth half as much as a bushel of squash, the farmer still is encouraged to look at expected yields and think about whether they'd prefer to grow 2 bushels of beans or 1 bushel of squashes....even if they cannot know if they will be able to sell any beans or squashes.

Johnny's Selected Seeds regularly undertakes trials to determine the yield of the seeds they sell and publishes the results in a table with their catalog (see following page). These and other attempts to make sanity out of an otherwise crazy business only serves emphasize the terrifying prospect of variable price and variable production in contrast to the relative security of grain production's secure price and (more) secure yields.

It is, at least, useful in planning what to plant for their families and workers...

Yield estimates for common fruits and vegetables follows on next page

Direct Seeded Vegetable Crops

	Average Seeds Needed Per:		Average Yield Per:	
Vegetable	100' Row	Acre	100'	Acre
Beans, bush	½-1 lb.	85 lbs.	80 lbs.	4,000 lbs.
Beans, pole	½ lb.	50 lbs.	150 lbs.	4,000 lbs.
Beans, lima	6 oz.	60 lbs.	12 lbs.	2,500 lbs.
Beans, shell	1 lb.	50-120 lbs.	8 lbs.	1,800 lbs.
Beans, soy	½ lb.	80 lbs.	20 lbs. fresh/12 lbs. dry	3,480 lbs.
Beets	½-¾ oz.	7-10 lbs.	40 lbs. green 100 lbs. roots	14,000 lbs.
Broccoli	¼-½ oz.	½-1 lb.	75 lbs.	10,500 lbs.
Brussels sprouts	500 seeds	70-100,000 seeds	60 lbs.	16,000 lbs.
Burdock	½ oz.	6 lbs.	60 lbs.	13,000 lbs.
Cabbage	¼-½ oz.	½-1 lb.	150 lbs.; 60 heads	31,500 lbs.
Cabbage, Chinese	¼ oz.	¼-½ lb.	60 heads	35,000 lbs.
Carrot	¼ oz.	2-4 lbs.	100 lbs.	30,000 lbs.
Cauliflower	⅛ oz.	4 oz.	90 lbs.; 60 heads	12,000 lbs.
Corn, sweet	3 oz.	8-15 lbs.	8 dozen ears	1,200 dozen
Corn, ornamental	6 oz.	25-35 lbs.	20 lbs.	2,900 lbs.
Cucumber	½-1 oz.	1½-2 lbs.	120 lbs.	17,500 lbs.
Endive	⅛-¼ oz.	10-16 oz.	80 heads	13,500 lbs.
Greens, Mustard	¼-½ oz.	2-3 lbs.	100 lbs.	29,000 lbs. (18" spacing)
Kale, Collards	¼-½ oz.	1½-1½ lbs.	75 lbs.	16,275 lbs. (24" spacing)
Kohlrabi	¼-½ oz.	¼ lbs.	50 lbs.	14,500 lbs.
Leeks	¼-½ oz.	2-3 lbs.	150 stalks	32,550 stalks
Lettuce	⅛-½ oz.	10-18 oz.	50 lbs.; 100 heads	27,000 lbs.
Melons	¼ oz.	1 lb.	100 fruits	15,000 lbs.
Onions, bulbing	½ oz.	5-6 lbs.	100 lbs.	38,500 lbs.
Onions, bunching	½ oz.	7-8 lbs.	100 lbs.	29,000 lbs.
Parsnip	½ oz.	5½ lbs.	75 lbs.	12,600 lbs.
Peas, fresh	1-1½ lbs.	240-300 lbs.	20 lbs.	4,000 lbs.
Peas, dry	½ lb.	200 lbs.	20 lbs.	4,340 lbs.
Pumpkin	1 oz.	4-5 lbs.	200 lbs.	40,000 lbs.
Radish, small	1½ oz.	25-26 lbs.	100 bunches	7,500 lbs.
Radish, Daikon	½ oz.	4-6 lbs.	200 roots	39,000 lbs. (20" spacing)
Rutabaga	¼ oz.	1 lb.	150 lbs.	40,000 lbs.
Salsify	¼-1 oz.	10 lbs.	60 lbs.	17,400 lbs. (18" spacing)
Spinach	½-1 oz.	8-10 lbs.	40 lbs.	12,500 lbs.
Squash, summer	1-2 oz.	4-8 lbs.	200 lbs.	30,000 lbs.
Squash, winter	¼-2 oz.	2-8 lbs.	200 lbs.	40,000 lbs.
Tomato	¼ oz.	½-¾ lbs.	150 lbs.	28,000 lbs.
Turnip	½ oz.	6 lbs.	100 lbs. greens 50 lbs. roots	40,000 lbs.
Watermelon	½-¾ oz.	1½-2 lbs.	70 fruits	18,000 lbs.

Transplanted Vegetable Crops

	Plants to expect from:			Days from setting	Average Yield per 100'
Vegetable	MINI	PKT	1 Oz.	plants to mature crops	
Beets	-	200	1,100	35-45	40 lbs. greens; 100 lb. roots
Broccoli	60	-	4,800	45-70	75 lbs.
Brussels Sprouts	60	-	5,000	100-110	60 lbs.
Cabbage	60	-	4,500	50-150	150 lbs.; 60 heads
Cauliflower	45	-	5,600	45-80	90 lbs.; 60 heads
Celeriac	150	-	37,500	100-120	60 lbs.
Celery	150	-	37,500	75-90	100 heads
Eggplant	15	-	3,500	50-75	75 lbs.
Kale	150	-	5,000	40-50	75 lbs.
Kohlrabi	70	-	4,000	30-40	50 lbs.
Leeks	200	800	6,000	75-100	150 stalks
Lettuce	250	480	20,000	35-65	100 heads; 50 lbs.
Melons	-	25	800	70-85	100 fruits
Onions, Bulbing	200	600	4,000	75-100	100 lbs.
Pepper	20	-	3,000	50-70	50 lbs.
Tomato	25	-	7,400	50-85	150 lbs.
Watermelon	-	20	400	70-85	70 fruits

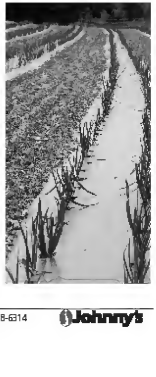
Feet of Row Per Acre

(1 acre=43,560 square feet)

Single Rows Distance Apart	Number of Row Feet/Acre
12"	43,560
16"	32,670
18"	29,040
20"	26,136
24"	21,780
28"	18,668
30"	17,424
32"	16,335
36"	14,520
40"	13,068
42"	12,445
48"	10,890
60"	8,712
72"	7,260

Rows/Bed on beds spaced 6 ft. on cntr.	Number of Row Feet/Acre
1 row	7,260
2 rows	14,520
3 rows	21,780
4 rows	29,040
5 rows	36,300
6 rows	43,560

Number of seeds to plant/acre: Find your row spacing on the chart. Multiply the corresponding row feet per acre figure by the number of seeds (plants) you plan to sow per foot to arrive at the number of seeds you will need per acre. Example: You plan to sow 20 seeds per foot on rows 24" apart. 20 x 21,780=435,600 seeds/acre.



Winter seasons and greenhouses increase overall productivity of the farm and allows year-round service to customers. Affordable ways of constructing greenhouses

Winter cultivation of fruits and vegetables improves the overall productivity of the farm, and allows the farmer to serve their customers year-round, an increasingly important need. This requires greenhouses: in those areas where greenhouses are not required in winter months, the farmer is not truly undertaking what can be called "winter" production, but is undertaking production in subtropical and tropical conditions which are more adequately defined by cool, hot, dry and wet seasons as opposed to summer, winter, spring and autumn seasons.

Greenhouses are typically not employed because traditional models of greenhouses are costly. Yet temporary greenhouses are easily constructed over the beds out of wood and plastic sheeting. These can cost as little as a dollar or two per bed-foot, which is sometimes 1/10, sometimes 1/2 of conventional costs.

It is an improvement over the cloche, a French microgreenhouse which, looking very much like a milk jug (and, for many farmers, is in fact a modified milk jug) sits over the plant. A cloche, meaning "bell" in French, is also sometimes used to protect plants form insect damage. Below are two examples. The top shows more traditional and professional (and expensive) cloches (photo from *Philip's Garden Blog* (philips gardenblog.com), the bottom demonstrates a more typical (and affordable) recycled use of plastic milk jugs (photo by David LaFerney, for his 2009 article *Starting Early in the Garden*). LaFerney's milk jugs have had their bottoms cut out and work almost as well as the heavy glass ones.





We do not use cloches, preferring instead to use temporary greenhouses. We do this because we plant many crops in a bed and cloches are best used for individual plants.

In a greenhouse, larger fruiting crops take up precious space, but yield a more valuable crop than smaller vegetative crops which take up less space and yield a less valuable crop. All things held equal, the farmer would likely continue to supply those crops which they had undertaken during their regular season. Happily, in this case, sprouts, spinach and zucchini all readily grow in a greenhouse, if there is sufficient heat.

The temporary greenhouse need not be very tall, and this reduces the cost of construction greatly. Building it only a few feet high, to accommodate the tallest of the crops, allows a lightweight, modular construction that is easily moved aside in summer. Having many small greenhouses is ideal: in case the farmer has a disease in one greenhouse, it does not infect the others.

Some farmers heat their greenhouses to increase production. With greater temperatures, the plants grow quicker. The amount of heat able to be provided and the cost of that heat depend on the structure of the greenhouse. A more permanent greenhouse can be made to be more energy efficient and also have facilities or electricity to produce great quantities of heat. Temporary greenhouses and cloches typically are unheated, except by what solar energy is trapped and retained by the soil under the cover.

Yet, even if temporary greenhouses are constructed and not heated, they may extend the season an additional 2-8 weeks, or all winter long in some areas.

Presuming the best of situations and the farmer can carry on all winter long as they did in the summer, the farmer can double their profits.

But, presuming the worst, that they only get two additional crops of sprouts, and assuming that they are aware of their limitations and plant a full crop of sprouts (5 times as many) at an expense of $2.50 per 100 feet to yield $90 of sprouts, they have increased their profits still by almost twice... if they can sell what they have grown at a good price.

And this illustrates, again, that all crops of a kind generally yield the same amount of profit per acre: sprouts, being a vegetable, earn about as much any other vegetable, and vegetables earn as much as wheat when all costs are considered.

A greenhouse is easily constructed by building a wooden frame and covering both the inside and outside surfaces with plastic sheeting. The reason for covering both sides is twofold: first, the trapped air acts as insulation, and second, if some damage were to occur to the outside (such as a bird landing on it and ripping it) or to the inside (such as a laborer accidently ripping it), the plants are safe until a patch can be made. If each panel of the frame has its own two plastic sheets (attached by staples, likely), it is easy to undertake repairs.

Constructing it as an "A" frame is better than squaring the roof because snow will not damage the peaked roof as much as a flat one.

The greenhouse need not be tall: more air space inside is more airspace to heat, and greenhouses not much bigger than the plants inside can be accessed through doors inserted into the frames and opened with hinges and handles.

Yet tall greenhouses allow for stacking plants on shelves and more total production per square foot of floor.

More sturdy greenhouses are necessarily better insulated. Glass panes hold heat better than plastic sheets, and a solidified northern wall will insulate against heat loss on the north side (no sun comes in anyway, in the northern hemisphere). Floors made of thick concrete or stones will absorb heat during the daytime and release it at night: further fortification can be made by making bricks of hydrated salt (fill plastic containers with salt and add enough water to moisten all the salt) or blocks of metal (salt is cheaper) or large rocks (which may or may not be cheaper than salt, but less effective in any case).

Electrifying a greenhouse so that electric heaters can warm it will increase production, but so will installing a fireplace and keeping a fire going. If possible, instead of a fire place, install a heating stove instead: these release less heat (up a chimney) and yield more warmth for less cost. Oil burning stoves are as effective as wood burning stoves, but the decision for what fuel to use should depend on what fuel is available and their relative costs.

Skylights on the roof increase solar radiation in the greenhouse.

Cooling the greenhouse in the summer is no problem for a small greenhouse: the farmer can simply remove it from the field! But a permanent, sturdy greenhouse will need to be shaded, ventilated and possibly cooled through ice or electric air cooling systems.

The flow of fresh air will be necessary, as the plants need to breathe. In less sturdy greenhouses there will be enough gaps in the construction; in those with soil floors, the ground will breathe enough air. But the installation of vents and sometimes fans to move air will be necessary.

It is better to have many small greenhouses instead of one large one: if disease should strike one of the greenhouses, the larger it is the more damage the disease causes. Also, large greenhouses are more difficult to heat and cool and ventilate.

Insects and arachnids should be allowed in: carnivorous insects will feast in your greenhouse, keeping it safe from herbivores. Weeds can be allowed or planted to accommodate these predators, but it is likely that this is unnecessary: the greenhouse itself becomes the shelter of choice for the predators.

Raising snails in the greenhouse or fish is possible, and may increase profits if the market prices of the meat is high enough. Fish are typically employed to clean the water in hydroponic systems, but this is as unnecessary as hydroponic systems.

If working in a permanent greenhouse, the farmer may opt for shelves of hydroponics or boxes of irrigated soil. Growing the plants in at least 6 inches of soil will reduce disease and improve yields, especially if the soil is tilled between rows: there are no aisles in the greenhouse, but the rows are hand-tilled as deep as the box will allow. Hydroponic systems with animal components (fish in the water reservoir, snails on a rotation, etc.) will reduce disease almost as effectively.

Trellises in larger greenhouses help the farmer more profitably raise larger plants such as squashes, tomatoes or peas. Allowing them to grow vertically improves space efficiency. But, such large plants are typically grown in very large permanent greenhouses, where the tall plants are stacked twice, sometimes three times under a giant roof.

Greenhouses, by the large cost of the structure itself, necessarily earn less than open field cultivation, but allow the farmer to produce in the winter for some measure of profit or loss (depending on market prices). Their chief function is to allow the farmer to provide a constant supply of food.

CHAPTER ELEVEN: OF WINTER WHEAT AND STORING WHEAT FOR BETTER MARKET PRICES

Though all plants gain benefit from deep hoeing, those that live longest need more food and necessarily gain more benefit from deep hoeing; winter wheat lives longer than most other kinds of grain

Though all sorts of plants enjoy great benefit from deep hoeing because the deep hoeing provides them with plenty of food at the time of their greatest need, not all plants equally require deep hoeing: those that live longest should have the largest stock of sustenance.

Generally, wheat lives (or ought to live) longer than other sorts of grain. Wheat lives longer because, if the wheat's seeds are to be fat and have much flour in them, the wheat must be sown before the spring. If sown in the winter, there is great danger from the frost delaying the wheat from establishing roots to feed itself: the sprouting wheat is maintained like a fetus by umbilical vessels to the ovum until the warmth of the sun enables it to send out sufficient roots of its own.

Wheat is usually sown in autumn and, because it is sown in autumn, wheat takes thrice the time that spring corn does and requires a proportionally larger supply of nourishment (not because the wheat in its infancy consumes very much more during the winter than it does in the spring and summer, but because during the long interval between autumn and spring, most of the artificial pasture is lost – in light and strong land alike).

Tillage, fallow and dung done once in the autumn does little by springtime

Some farmers fallow and dung the soil, believing it necessary to feed the wheat. But, notwithstanding all their labor and expense, the ground is generally so stale by spring and provides so little benefit to the wheat that survived their efforts that, had the same field been sown in April upon fresh plowing – without dung or a year's fallow – the wheat would yield as great (or a greater) crop.

Poor light land, in the common husbandry, must be very well cultivated and dunged to maintain wheat for an entire year (which is the usual time that wheat grows). In the ordinary method, if the wheat is sown late it will seldom survive the winter, and if sown early – even if on rich land that is well dunged and tilled – it will be worse than on poor, light land sown early. The long winter rains cause the soil to subside, bringing the divided parts to coalesce and lock out the roots, causing the wheat to starve (like Tantalus) amid a plenty that tempts the roots but may never be attained by them.

But my new method of deep hoeing gives strong and light land all the advantages and takes away all the disadvantages of both (as I described in the chapters on tillage and hoeing). By my new method, strong land may be planted with wheat as early as light land, and the plow (if correctly applied) can raise pasture equal to that of dung.

Using the seed drill for wheat is successful

About the year of 1701, when I had just contrived my drill for planting sanfoin, I made use of it also for wheat. I was able to drill many rows at once: this made the work much more compendious – the drill performed it better than hands could do. My drill made the channels 12" apart, drilled in the seed and covered it for no more cost than 6 pence per acre (which was 10 times over repaid by the savings in seed). One bushel to an acre was the quantity drilled and there remained no need of hand work...only hoeing (and this cost less than a half a Crown to four shillings per acre).

This way of planting turned to a very good account and yielded considerable quantities. It has brought a better crop of wheat on barley stubble than that sown in the common way onto a summer fallow: when sown in the common way onto the same land, the crop entirely failed. The only difference between the crop that failed and the crop that succeeded was the drilling and the hoeing.

Tullian agriculture improves ground

The new method of planting was also such an improvement to the land that when a strong whitish ground (of all equal goodness, equally fallowed and tilled) was divided in two parts, the first dunged and sown in the common manner and the second part was drilled and hand hoed without dung, the hoed part was not only the best crop but when both parts were fallowed the next year and sown alike by a tenant, the hoed part produced so much a better crop of wheat than the dunged part that a stranger would have believed that the part that had been dunged was not, and the part that had not been dunged really was!

Tillage can prepare even grassy pastures for wheat

There is seldom any land so unfit or ill prepared for wheat as those lands where natural grass abounds. One bunch of natural grass, transplanted by the plow into a treble row of wheat, will destroy almost a whole yard of it. Most other sorts of weeds may be dealt with when they come among drilled wheat, but it is impossible to extract grass from the rows and they must be killed before the wheat is planted.

Beds of wheat should be separated by 72 inches

Beds of wheat ought to be separated by 72 inches.

Contouring beds and aisles along hills makes tillage difficult

If there is a hill in the way of the rows, cause the rows to run up and down it – not follow the contour of it: this will allow you to more easily till and hoe. If the rows should go across a hill, they

would not be well hoed: it is difficult to turn a furrow upwards or downwards without burying the plants in the rows.[216]

Make beds and aisles equidistant by use of sticks in the ground laid along a string, the string is laid in the correct path and removed when the sticks are inserted; the sticks get plowed under

Ridges should be made straight and equal, but all good plowmen know how to make them straight. If the piece of land is in a crooked or serpentine form, it suffices to make the rows all parallel and equidistant. To make the rows straight or equidistant, set up short sticks at the ends of the land to mark the beds and aisles, and lay a string between the two ends of the land. Line the string with sticks, remove the string and follow the sticks when plowing.[217]

Align beds and aisles parallel to the horizon of subirrigated sections so that you need never put off hoeing an aisle because half of it is wet and unable to be hoed while the other is dry and ready

If one side of your field remains wet while the other remains dry, align your beds parallel to the horizon of wet and dry: if you don't, you might need to hoe a bed when half of it is wet and unable to be hoed.

Height of ridges should be 6 to 12 inches tall, but dependent upon the soil and climate conditions, this may be significantly different from what is required

The exact height of the ridges caused by plowing that is best I have not yet determined. I have found that none of my ridges are quite 12 inches tall, and some of them only 6 inches...though they are taller in the spring after the troughs subsided in the winter. A different soil would require a different height, according to the depth, richness and the degree by which the soil has been pulverized.

Wheat likes to lie dry in the winter: do not plant in the troughs

Wheat likes to lie dry in the winter, and there is no few ways better to keep it dry than ridges that are 18" wide, with troughs more than a foot deep on either side: the winter rain will fall to away on either side quicker than if planted the wheat were on the level. Water, when it runs off very quickly is very beneficial (as can be seen in watered meadows: where the water remains long on or very near the bodies of terrestrial plants, it kills or injures them).

[216] And, wheeled machines will sometimes slip downhill! Yet, it is better still to terrace a hill along its contour to better reduce erosion while allowing for tillage. —A.B. & M.C.

[217] We find that small colored flags, colored cloth or other artificial markers are superior to sticks: they are more visible. –A.B. & M.C.

Use wider beds for wheat: wheat is typically planted in treble rows

You should not leave the tops of the beds so narrow or sharp for drilling wheat as you would for drilling turnips: wheat is planted in treble rows and turnips are planted in single rows; the wheat requires more width.

If the beds are not to be tilled before replanting, in reaping, cut as near to the ground as possible so the stubble is no impediment to the drill

In reaping, I cut as near as I can to the ground (which is easily done because the stalks stand all close together at the bottom, contrary to those of broadcasted wheat). Reaping low to the ground makes the stubble no impediment to the drill. I find that this stubble is very beneficial to the hoeing of my wheat, but I do not know whether it is beneficial to rich miry land.

While it may be impossible to and the beds may need to be reused without tillage due to weather, it is best to alternate beds and aisles and till the beds before planting

As soon as you conveniently can, after the crop of wheat has been carried off, go as near as you can to the stubble with a common plow and turn two large furrows into the middle of the aisles. This will make a ridge over the place where the trenched aisles were. Continue tilling as long as the dry weather lasts, turning the aisles into beds and the beds into aisles. Then, dig deeply into the new aisles (where the old beds were) and turn the soil up into the beds (where the old aisles were), piling it higher and higher. To make the beds very high sometimes requires very wide aisles from which to take soil. Making the new beds on top of the old aisles has this further advantage: though the beds are no higher than before, because the aisles were lower than the level of the field, the beds are now deeper than the level.

It is necessary to harrow the beds once (lengthwise) before planting, to level the mound.

Wheat ought to be protected from the winter's cold air by compacting the ground above it or covering it with more soil and keeping the beds dryer

It is a general rule that all sorts of grain and seeds prosper best when sown when the ground is neither too dry nor too wet, when the soil may be broken into the most parts by the plow. The reason why wheat is an exception to this rule is because it must endure the rigors of winter (which it is better able to do when the soil is compacted around it — when it is sown into wet soil). It is for this very reason that farmers will drive their sheep over light land as soon as it is sown with wheat: to tread the surface of the soil hard so that the cold winter cannot so easily penetrate and kill the tender seedlings.

If wheat were as hardy as rye, whose roots are patient of cold, it might (no doubt!) be sown in as dry a season as rye is and prosper better for it (as rye does). But because wheat requires the soil to lay heavier upon and about it during the winter, so it also requires more help in dissolving the soil about its roots when the winter is past. Rye does not require so much manure or tillage as wheat because its soil was never compacted as much as wheat would require.

Planting into dry soil is a mistake. Wheat does best when planted into a moistened bed. If necessary, wait weeks until the newly tilled beds are moistened by dew and then cover the seedlings with fresh soil

All sorts of vegetables thrive best when sown on fresh tilled ground immediately after it is plowed. But wheat is an exception to this rule also, for it is better to plow the ground dry and let it lie until the weather moistens it (even if it is several weeks before the ground is moistened) and then drill the wheat: the harrows and the drill will move a sufficient part of the ground to nourish the wheat and leave the rest undisturbed to protect the wheat against the cold winter.

This said, there is a kind of soil that is like bound sand that requires not only to be plowed dry, but sown dry as well: if it is not, the what will dwindle in the spring and fail to be a tolerable crop.

Dry plowing versus wet plowing

What I mean by "dry plowing" is not that the land is so void of moisture that the dust flies, but that it is not so wet as to stick together. I do mean that the dryer, the better. I do not drill when the earth is wet as pap. It suffices that the soil should be moist, but moister in lighter land than on strong land.

If the two furrows that the treble row are to stand upon is plowed wet, the soil between the rows will grow so hard by spring that the roots will be unable to run freely therein. A steep bank, made of wet soil, will lie fast or many years while another made of the same soil when dry will erode very soon: this is because the dry soil has not the cohesion that the wet soil does. The greater porosity of the dry soil brings it to crumble down. The greater porosity of the dry wheat bed makes it easier for the roots to penetrate.

Drilling into wet soil is a mistake: the ground compacts too hard for the wheat to thrive

I have seen trials of this difference between plowing dry and plowing wet in planting wheat, both in the old way and in my new drilling way (but more in the latter) and never saw an instance where the dry plowing did not outdo the wet—so long as the wheat was planted before the soil was become moist at the top.

Strong land plowed wet in November will be harder in the spring than if plowed dry in August, even though it has three more months to lie and harden.

After rain, when the top of the ground is of a fit moisture for drilling, harrow it with two light harrows, drawn by a horse going in the furrow level to smooth it for the drill.

If the veerings[218] upon which the next crop is to stand are plowed dry, you may drill at any time during the common and usual times for seeding wheat. But I have had good crops of wheat drilled at all times between harvest, even when it was planted as late as November. But because the

[218] I believe that the word "veering" is taken from the seamen and signifies "to turn." It is the plowman's term for turning two furrows toward each other, as they must do to begin a ridge. Therefore they call the top of a ridge a "veering" and they call the two furrows that are turned from each other at the bottom between two ridges a "henting" (an "ending") because it makes an end of plowing ridges.

soil must be dry, the seed can only be planted earlier or at the same time as the farmers who do not drill: we can drill earlier, but not later than the common method.

If planting three rows of wheat, it is best to plant later than earlier and dryer to avoid compaction

For the benefit of the middle rows, it is better to not drill wheat on strong land before the usual season because the later it is planted, the more open the partitions will be for the roots of those rows to run through them in the spring. And yet, if the soil of the partitions were plowed when very wet (even if they were plowed late), they may be harder in the spring than those that were plowed early and dry.

The Smyrna Wheat variety is best

There is a kind of wheat called Smyrna Wheat. It has a prodigiously large ear with many lesser (collateral) ears coming all around the bottom of this ear. It is the largest of all kinds of wheat. It can devour the entire nourishment of a garden without being overfed, and requires more nourishment than the common method will afford it. In the common method, its ears do not grow much bigger than the common wheat, but it is ideal for my method. I esteem it the best for the horse hoeing husbandry, next to it I esteem the white-cone wheat, then the grey-cone. I have had very good crops with other kinds of wheat, but these three I look upon as the best.

When wheat is planted earlier, it will tiller more, fewer seeds will die and less seed is required

When wheat is planted early, less seed is required than when planted late because less will die in the winter and it has more time to tiller.[219] Poor land should have more seed than rich land because a less number of the plants will survive the winter on poor land.

The least quantity of seed may suffice for rich land that is planted early because very few of the seeds will die, and the hoe will cause the small number of plants to send out a vast number of tillers. These tillers will all have large ears and it is the amount of grain (not the number of plants) by which the goodness of a crop is best judged.

Some varieties of wheat grow bigger than others and require fewer seeds

Another thing that must be considered to find the best proportion of seed to plant: some wheat has grain twice as big as others of the same kind.

A bushel of large seeds contains fewer seeds than a bushel of small seeds; it is not the weight or volume of seeds, but the number that matters when measuring the quantity required to plant a field; origin of the use of bushels as a measure of volume and weight and the origin of the acre as a measure of area

[219] Tillering is to branch out into many stalks, and is the country word that means the same as "Fruiticare."

When grains are larger, a bushel will contain but half the number of grains. One bushel of small grained wheat will plant as much ground as two bushels of large grained wheat: in truth, it is not the volume or weight of the seed, but the number of grains that matters when measuring the quantity required to plant a field.[220]

[220] The bushel is a very strange form of measurement: it can be used as a standard weight or a standard volume. Its origin lies with the development of the acre:

By about 5,000 BC, all sorts of things were being invented, not least among them a standardized unit of measurement. This unit of measurement was based on the circumference of the Earth. From experiments and observation, people understood that the earth was a sphere and that it rotated on its axis. Rather than measuring the time of rotation based on either the moon or the sun (the sun and moon rise and set at different times each day and are not constant), people measured a "day" by the time it took for a star to return to its original position in the sky: stars do not "move" in the same observable way that the sun and moon do.

Well, as soon as it was decided that stars were better to measure the rotation of the earth by, it was observed that the earth rotated around the sun: a star would not return to its original position for 366 days! Thus, in original geometry, the circle had 366 degrees, not 360 (it was shortened by 6 degrees by the Sumerians to make math easier).

A person could stand outside at night and divide the horizon into 366 degrees, and then observe the time it took for a star to pass between that one degree by use of a pendulum. If the pendulum's length was "correct" (a standard size), it would take 366 swings for a star to pass between the two degrees on the horizon. Which star to use? It had to be an easy one to find. Venus is the brightest star in the sky, and even though Venus has a changing speed during the year, they calibrated their pendulums on the day of the year when Venus moves the slowest. The length of this pendulum was the foundation of all modern units of measurement, and is known to archeologists as the "Megalithic Yard." The Megalithic Yard (MY) is similar in size to the Meter, and measures roughly 2.722 Feet (82.966 Centimeters). The Megalithic Yard was divided into 40 units, called "Megalithic Inches" (MI).

By making a cube with each side the length of 1/10 of these Megalithic Yards (4 MI) and filling the cube, standardized units of volume were developed. This unit of volume is now called the Pint. A cube with a length of 8 MI is called the Gallon. A cube with a length of 16 MI is called the Bushel.

If the same volume is filled with water or seed, units of weight can be found. Grain (Barley seed was used by the ancients) occupies about 125% of the volume of water when placed in a cubical container. When a Pint is filled with barley, it weighs one pound. However, some of the ancients filled the Pint with water, and called it a pound. The difference between a Pound Avoirdupois and a Pound Troy is thus explained.

When 40 MY are squared, the resulting area is known as the Irish Acre (23,520 square feet). 75 MY x 100 MY equals the Scottish Acre. So where does the modern acre come in?

As the megalithic peoples based all numbers off of the 366 degrees of the earth's rotation, the Sumerians based all their numbers off 360 degrees of the earth's rotation. 6 MY described a "Megalithic Rod." When an area is made measuring 4 MR x 40 MR, you get the modern Acre. This can also be described as being 16 sections measuring 360 MY in area. The modern acre originated from a time after the Sumerian improvement of rounding down from 366 degrees to 360 degrees: the Sumerian-influenced peoples made their acre to have 360 squares in reference to the 360 degree system. Further evidence of the modern acre being the result of Sumerian improvement can be seen

Small grains do not necessarily make small plants

Some have thought that a large grain of wheat would produce a larger plant than a small grain. However, I have full experience to the contrary. The small grain does indeed send up its first single blade in proportion to its own bulk, but can afterward becomes as large a plant as the largest grain can produce.

4 to 6 gallons of middle sized seed is usually required per acre

in how the modern acre of 43560 square Feet may be divided evenly into 121 (11 x 11) sections of 360 square feet.

Though the Sumerian-influenced descendants of the megalithic peoples attempted to simplify the megalithic accounting, they still used the same methods of dividing land; their ancestors divided land into units of 366 square feet and they divided land into sections of 360 square feet.

The ease of the Sumerian system was eventually improved by bringing it into conformity with a base-ten system. The French are usually given credit for this "metric" system. The Meter was developed using the Sumerian 360 degree circle as a starting point. Thus, the metric system is based off of the Sumerian improvement to the megalithic system. Thomas Jefferson, like the French when they developed the metric system, wanted to improve the Sumerian system by bringing it into conformity with a base-10 system. He attempted to introduce to the newly formed United States his better form of measurement based on a 360 degree circle. But, unlike the Meter in France, the Jeffersonian Units of measurement never caught on.

Was Thomas Jefferson's improvement new? 1,000 Jefferson Feet (Jefferson's units were to be referred to as Jefferson Feet, Jefferson Miles, etc.), was 360 MY. However, 1,000 Minoan feet had equaled the same distance for thousands of years before Jefferson: the ancient Minoans had the same idea as Jefferson and ought to be given credit for bringing the Sumerian improvement into a base-ten system.

At least we have not had to reinvent the clock! Before the innovation of a base-ten system of numbers, people used a base 12 unit of measurement. This base 12 system was devised after observing that the Earth rotates around the sun every 366 rotations about its axis (said another way, the Earth will rotate on its axis 366 times before returning to the same relative position to the sun).

Later, this 366 degree system was altered to become a 360 degree system (for the ease of mathematicians) and the 365 day year was established (before that, there was a 6 day week, and 61 weeks to the year – a easy-to-see remnant of the old 6 day week may be found in Bible, which divides the act of creation into 6 days). Before the 365 day year, there was the 24 hour day and the 6 day week.

24 hours x 366 days = 8784 hours per year, or 8784 hours divided into 61 weeks of 144 hours. Each week was 6 days x 24 hours long (144 hours = 12 x 12. 12 hours is significant because they worked with a base 12 system as we work with a base 10 system). Those interested in learning more about units of measurement would do well to read Alexander Thom's *the Megalithic Sites in Britain* (1955), *Megalithic Sites in Britain* (1967), *Megalithic Sites in Britain* (1968) and *A Statistical Examination of Megalithic Remains in Britain and Brittany* (1978). Also, D. C. Heggie's *Megalithic Science* (1981), J.W. Graham's, *Palaces of Crete* (1962) and Christopher Knight's *Civilization One*.

I will typically drill 6 gallons of middle-sized seed on an acre, yet on rich land planted early, 4 gallons will suffice because the wheat will have roots at the top of the ground before inter and tiller very much without the danger of worms or other accidents that late planted wheat is liable to.

If drilled too thick, the wheat will be in danger of falling. If too thin, the wheat will tiller so late in the spring that some of the ears will be blighted. But a little thicker or a little thinner does not matter very much.

Typically plant 1/2 to 3 inches deep

As to the depth, you may plant from a 1/2 inch to 3 inches deep. If planted too deep, there is more danger of it being eaten by worms between the grain and the blade (that thread is the thread of life during the winter – if the wheat is not planted too early). The longer the thread is, the greater the danger of the worms because a worm can more easily find a thread that extends 5 to 6 inches than one that extends but a single inch, and also because worms do not live very near the surface of the ground in winter. A wheat plant that is not planted early sends no root above the grain before the spring and is nourished all winter by that singe thread that proceeds from the grain to the surface of the ground.

Rooks eat wheat sprouts, so keep them off the field for 7-10 days after emergence, or plant when there is enough grain from the previous harvest to distract them

It is a necessary caution to beware of the rooks just as the wheat begins to peep. Before you can perceive it to be coming up, the rooks will find it and dig it up to eat the grain. Therefore, keep them off of your field for a week or ten days until the blade becomes green and the wheat has exhausted its grain's flour that the rooks do not think it worthwhile to dig it up.

But the rooks do not molest wheat before or a little after St. Michael's Mass: then there remains enough grain in the fields from the last harvest[221] that the rooks prefer to eat more than the sprouting wheat: the sprouting wheat costs them the labor of digging to find it, whereas the grain on the surface of the ground costs them nothing.[222]

On multiple rows per bed

The double row has only one space between rows, which makes it advantageous to use when the land is suspected to be full of the seeds of weeds that will need to be taken out by the hand hoe.

[221] We have found that for a small price of grain left on the fields as a "present" to the birds, the seeds that are planted are (generally) left alone. –A.B. & M.C.

[222] Jethro Tull is quite correct in analyzing the behavior of animals and plants through economic mathematics. Allow free entry and exit to your fields to all creatures, induce a free economy and, through the competition that arises between all plants, animals, fungi and microorganisms, no creature will ever find itself out of balance with nature. Capitalism (which is, ultimately, the true philosophy of all creatures) demands freedom, liberty and equality... and a governor (farmer) that can prevent disaster during natural swings of adjustment. –A.B. & M.C.

Double rows separated by one foot; in planting, margin of error can be as great as 2 to 12 inches, or more: smaller plants have less margin of error

I choose to make the space between the double row one foot wide, though the difference between 12 inches and 14 inches is so little[223] that it is scarcely worthwhile to set a drill on purpose. To plant these double rows at the common distance of fourteen inches without altering the drill is not a problem. I have found that whole fields drilled with a distance between rows of 12 inches may be hand-hoed at the expense of four shillings per acre.

Triple rows have 7 to 8 inches between rows

The common width of the two partitions of the treble row is either 7 or 8 inches each. To find out the best distance in planting these rows, I made one of the partitions 6 inches, the other 9 inches. After being harrowed by a common harrow equally, I observed that in the springtime there was not an equal distance between the rows in all places. This may have been due to the harrow disturbing the seeds and bringing some closer and others further from the middle row, and the hoe plow then not going equally distant from all the plants in either outside row.

I have, for some years, planted my treble rows at 7 inches apart. I find them succeed better with wider partitions: I observe that the better the land is (whether by nature or culture), the less distance there must be between the outside rows and the middle row. The two outside rows risk injuring the middle row by being too close to it, or by being too far: when too close, they crowd out the middle row; when too far, the distance prevents the middle row from obtaining much nourishment from the hoe.

[223] We would argue that even 12 inches is almost too small to bother with for accuracy for some of the larger crops: the accuracy required is dependent on the number of crops in the bed, and the size of those crops. A plant that is supposed to be planted every 3 feet can tolerate a 12 inch variance better than a plant that is supposed to be planted every 3 inches.

In dryland circumstances or with some cereal crops, the plantings spacing will be exaggerated so that the plants will have enough water. In some deserts, it is necessary to space each corn plant more than 72 inches apart in the row! In these dramatic circumstances, first dig a trench and then seed in the trench. When the crops begin to grow above the trench, fill in the trench to cover the crown of the plant and protect it from dehydration. You can also plant on the level (which is easier for seed drills) and mound the soil (as Tull directs) over the crowns.

The mound technique is native not only to Europe, but also to America. The nations of the Americas that governed before the United States was formed would plant corn with squashes and beans all in the same spot in the row under a mound of soil: they found that these three plants together will do better than anyone would independently. The polycultural colony collectively does better because the plants with the greatest roots (the corn) brings water to feed the beans and squashes, while the squashes shade the roots of the corn and beans to help retain the hard-earned moisture, while the beans climb the stalk of the corn and shade not only the corn's body against the harsh heat, but the leaves of the squashes as well. –A.B. & M.C.

Do not have rows less than 4 to 5 inches apart as this will make a barrier to the roots of the other row when they try to access the aisle for food

In a large, poor field, drilled with wheat in double rows, the distance between the rows was more unequal than usual in the parting space (the parting space is the distance the drill leaves between rows it plants going one way and the rows it plants coming back – this distance cannot be supposed to be equal in all places as the distance between rows planted in one pass by the drill can be). After this wheat was taken off, I observed by the strength of the stubble that in those places where the parting space happened to be only 4 or 5 inches, the stubble was as thick and strong as where the parting space was 18 inches or more...but where the rows came together closer than 4 or 5 inches, the stubble was smaller and weaker.

By this it may be inferred that where the parting space was widest, it gave no more nourishment to the two rows (in summer) than what was balanced by the greater distance their roots had to pass before they could reach through to the opposite aisles. The wider the aisles, the fewer roots will pass all the way across it: roots spread from a plant like radii of a circle from its center.

Each row to each plant in the opposite row is like the chord of an arc: the further it is from each opposite plant (or center of radii), the fewer the radii (or roots) will be intersected by that row. Where the rows approached too near together, they were stunted when they were young and before they could have the benefit of the hoeing. The two rows having, as it were, no aisle between them. They could have but half the nourishment they would have had if the aisle had been wide enough to half maintain them in their infancy.

Four rows per bed are not usual, space rows 14 inches apart: it is nothing but two, double rows

I have not, as yet, made a drill on purpose for quadruple rows...but I make some of the treble rows every year with my treble drill in this manner: when I take off the foremost hopper, the drill plants seeds 14 inches apart. The horse, returning back, goes on one of these two rows and plants one more row between the previous two and then one on the outside. This makes four rows, though by this way the distances will always be uneven: either the distance between the middle two rows will be wide and the distance between the outside rows will be narrow, or the distance between the middle two rows will be narrow and the outside wide.

When there are four rows per bed, it is better to have outside rows closer than the inside rows closer. If inside rows are closer than 6 inches, they yield less than a single middle row.

It is better to have the outside rows close together than to have the middle rows close together: I have observed that when the middle two rows are very near together (closer than 6 inches), they yield less than a single middle row. If the two outside rows are close, I have observed that the two middle rows yield more than a single middle row. Hence I conclude that quadruple rows should have at least 6 inches separating them.

Quadruple rows require no more bed width than triple rows, but the middle two rows are not ever as good as the middle row of a triple (treble) row

These four rows are only 18 inches across, and do not require any wider of a bed than the treble rows do.

Neither of the two middle rows in a quadruple row is as good as the one middle row in a treble row. This difference is a proof that the middle rows receive nourishment from the aisles.

If the soil is poor, increase the height of the bed or decrease the width of the bed

If by the shallowness of the soil, the narrowness of the plow or any other cause, the furrows are too small to raise the ridges high enough at once, you must raise them higher by plowing twice (or else expect the middle row to be less for want of pasture underneath it). Or else, you can have narrow beds so that the pasture that is wanting from below may be supplied from either side.

Plant with low density to prevent the outside rows from robbing the middle rows (or, in the case of double rows, their twin) of food from the aisle to which they are adjacent

When planting treble or quadruple rows, the rows must be planted sparsely. If the middle rows are planted with too many seeds, the plants will be weaker and less able to send their roots into the aisles early in the spring. And if the outside rows are too thick with plants they will rob the middle row by forming hedges that obstruct the middle rows from reaching the aisles.

I remember that when the roots of my row that I found had reached the aisle at 18 inches distance (which was then the full height of the plants) which had passed through another row in their way only were able to because both rows were thin of plants and the land was made very fine and friable.

Raised beds are sometimes best

Land made very fine and friable makes some little amends for the want of ridges and may be planted upon the level. Yet I always find that ridges, by the advantages they have above land that is level, do bring the best crop and are more easily managed.

Villainies of hired labor will result in land plowed too shallowly

It is no small advantage in this management that whether the veering or the henting is left in the aisle by the hoe plow all the furrows in a whole field lie continually open so that the master cannot be cheated by his plowmen who might otherwise persuade him they plowed deep when they plowed shallow! But in the common plowing, all the furrows may be shallow except the last two of every ridge (which has perhaps 40 furrows, 38 of which are always lying covered). It is not easy to

know how deep they are plowed and of all of the villainies of English plow servants, this trick of plowing too shallow has undone the most farmers.[224]

Middle rows require deep soil – it insulates from the weather, provides extra food, and impacts soil moisture content

I could never bring my middle rows to be anything near equal to the outside rows until June 19, 1731, when I did it in both the quadruple and treble rows.

The soil was all thrown out of the middle of the aisles before the last harvest (after being well pulverized). Then, sometime after harvest, when the soil was dry, it was raised up to a pretty high ridge in the middle of each aisle from which it was taken. When the weather had made it sufficiently moist, the wheat was drilled upon it with 7 inch partitions: this wheat flourished all winter and spring, and the middle rows were equal to the outside rows in color and height in both the treble and quadruple rows. All the drilled rows were stronger than the adjoining sown fields, though the sown fields had been manured, fallowed and four times plowed (mine being without manure for many years past).

The deep pulverized soil keeps the plants strong in the winter and spring, which enables the middle row to send out its roots more vigorously through the roots of the outside rows (which, if they were on shallow soil, would bar the roots of the middle row – the roots are thickest near the stems).

Well pulverized soil is essential if the middle rows are to reach the aisles

When the plants of the middle row are too numerous for the pasture of the partitions (for want of a sufficient depth of pulverized soil), they are weak and unable to send out their roots vigorously enough to reach the aisles in time. Also, when the plants of the outer row are too numerous on a shallow soil, the roots of the outer rows (which are always thickest near the bottom of the stems), make a hedge between the roots of the middle rows and the aisle. This hedge obstructs the passage of roots from the middle to the outside. But, when the soil is deep and well pulverized, the roots of the inner rows are able to go deep under the outside rows to the aisle.[225]

But if the hoe plow does not at the first hoeing go deep and near to the beds, the subsided soil will, especially in strong land, be like a wall to confine the roots of all the rows from entering the aisles in the spring and summer (which is the time that they require the most nourishment from it).

Experience has shown me this year that the reason that the middle row falls short of or only just equals the outside row is because of the distance of the middle row to the aisle. On about 60 acres of wheat I now have near ripe, there is not one row – whether treble or quadruple – where the middle row (or rows) does not succeed. Any middle or inner row that has a competent number of

[224] An excellent argument for either doing the work yourself, or employing better labor management practices to ensure the work is done well. –A.B. & M.C.

[225] Whether using raised beds, as Tull advocates, or level beds (as is advisable in dry climates), there remains the need to pulverize the soil very well and very deep. While this is more difficult when planting in a level bed than on a raised bed (or a bed planted on the level), it is still possible...and necessary! —A.B. & M.C.

plants, standing in a competent thickness on sufficiently well pulverized soil will succeed as well as the outside row. However, if the number of plants is too great or too few, if the density is too great or too little, if the soil is not pulverized sufficiently, then the outer rows may send their roots into the aisles to be better nourished while the middle or inner rows cannot do so well.

Hoeing wheat – never hoe before the wheat has one leaf

The first hoeing is performed by turning a furrow from the row to the bed.

The weather does not matter much to the first hoeing: if the soil is wet, the hoe may go nearer to the row without burying the wheat and the frost of the winter will pulverize the part of the furrow that is to be thrown to the wheat in the spring (though it was hoed wet).

Neither does it matter much what time it is hoed, but it must never be hoed before the wheat has one blade – and that is soon enough, for it often has four or five leaves by the beginning of winter.

Hoe as closely as possible to the plants

The greatest faults that you can commit in hoeing are to not go near enough to the plants or deep enough. You cannot go too near it (unless you plow it out or bury it with soil or uncover the plants), or go too deep.[226]

Servants are apt to hoe too far from the rows for fear of damaging the plants

Servants are apt to hoe too far from the rows, going backward and forward in the middle of the aisles without coming near to the rows. This loses most of the benefit of hoeing and is injurious to the present crop. Hoeing his way leaves a deficiency of pulverized soil: the pulverized soil is too far from the rows for the roots of the plant to reach into it...and those plants that can reach come there too late to bring the plants to their full perfection.

When using a mouldboard plow, hoe into the aisles during the winter to improve drainage and then hoe towards the beds in the spring to give the wheat more food when it requires it

Always leave the furrows turned up to make ridges in the middle of the aisles during winter, and then the hollow furrows next to the rows, having been enriched by the frost and rain, will give the wheat earlier benefit in the spring than if the trenches had been left open in the middle of the aisles. Frost, if it does not kill the wheat, is of a great benefit to it: the water, when it is frozen in the soil, takes up more room than when liquid. This swelling of the ice moves and breaks the soil like hoeing. When the ice thaws, the cavities are left hollow and open. This benefit of the frost is seen mostly near to the surface, and so by increasing the surface area of the land by turning up the furrows, there is more advantage gained by the frost.

[226] We hoe even to within an inch of plants, and, when it is possible under the constraints of time and equipment, even two feet deep or more! –A.B. & M.C.

The outside rows of wheat, from which the soil is hoed off before or in the beginning of winter is left almost bare until the spring. You would think that they should suffer for the frost coming near them or for want of pasture, but in practice it appears quite the contrary: where the hoe has gone nearest to the row, the plants thrive best. The soil, which the frost has pulverized, being within the reach of the young, short roots on that side of the row from the top to the bottom of the trench nourishes them at first and before the plants have exhausted this, as they grow larger in the spring, the ridge from the middle of the aisle is thrown to them. Then they have an unexhausted pasture to supply their increasing bulk with more nourishment.

In very light land you probably should not hoe quite so near to the rows of wheat as in strong land for fear that the winter will find the roots bare and expose them too much to the cold. Besides, in light land you may be sure that the roots will find the aisles easier than in heavy land and therefore does not require the hoeing to be as close to the row as in heavy land. Yet, such very light land is not proper for wheat.[227]

Because the row stands (as it were) on the brink of this almost perpendicular ditch, the water runs off of it quickly, or does not enter but a little way into this steep side so that the soil of the plants is almost dry. This dry soil the frost does not penetrate well, and the roots of the plants are unhurt by it. Though the distance from the air to the roots is small, the dry soil does not freeze as wet does, neither is this ditch much exposed to the cold winds.

Autumn tillage enriches the soil during the winter

It is a vulgar error that the winter rains do not enrich the soil, and it is only thought so because we do not see the effect of the winter rains upon the vegetables for a lack of heat in the season. But farmers have frequently observe that one half of a ground plowed up just before winter has produced a crop of barley much better than the other part plowed up at the end of winter.

Spring hoeing is performed as soon as the weather will allow it

The spring hoeing is performed at the time after the greatest frosts are past and as soon as the weather will allow it. At this time, plow from the rows into the aisles, even so close as an inch from the plants. Then turn the ridge from the middle of the aisle to the rows on each side, as close as possible without covering the wheat. In doing so, have regard to the row only, without looking at the middle of the aisle – it is no matter if a little soil is left unmoved in the aisle, the next hoeing will move it.

[227] Though not proper for wheat at the first, the land will continue to improve through good husbandry. We have found that large-seeded plants (such as peas and squashes) as well as plants that are highly salt tolerant (and therefore dehydration tolerant, such as beets, spinach, lettuce, dandelion, radish, quinoa and sunflowers) do well on this light land that wheat does not do well on at first. In later years, any crop will do well on the land – whether drought tolerant or flood tolerant. –A.B. and M.C.

Inverting the soil improves immediate fertility, stirring improves long-term fertility

It is the errant mistake of the vulgar when they imagine the immediate benefit of the fresh soil to the plant is from that part which remains uppermost. It is the turning of the fertile side downward to be fed to the roots that gives the plants their food. The side which was not so fertile, being brought to the surface, will become fertile soon.

How often should wheat be hoed in summer? Do not let the soil grow hard

As to how many times wheat is to be hoed in the summer after the spring hoeing, it depends on the circumstances and the condition of the land and weather. But the season be as it will, never suffer the weeds to grow high or let any unmoved soil lie in the middle of the aisles long enough to grow hard.

Do not plow deep near the rows in the summer when plants are large, but till deep in the middle of the aisles

Do not plow deep near the rows in summer when the plants are large, but plow as deeply in the middle of the aisles as you can, turning the soil to the wheat, leaving a deep, wide trench in the middle of each aisle.

Hoeing near the plants when small breaks off the ends of the roots, but after the roots are spread far into the aisles, hoeing in the middle of the aisle will do the most good: hoeing too close to them will break off too much of their roots. Yet you may hoe shallowly as near to the mature plants as you like without damaging the most of their roots – this will be most advantageous to them.

Poor land needs more hoeing, land not previously well hoed needs more hoeing

If land was not sufficiently tilled or hoed in the precedent year, it will require the more hoeing in the next year. The poorer the land, the more hoeing it should have. A wet summer will prevent some of the hoeing.

Improve wheat yields: increase the number of stalks, not the number of plants

My method increases the yield of wheat not by increasing the number of plants, but by increasing the number of stalks, ears and grains, and increasing the size of the grains.

By increasing the number of stalks from one two or three to thirty or forty to a plant, the yield is increased if these stalks are then brought to grain. The common method typically does not see more than half the stalks come to grain, and, typically, less than 1 stalk of 10 comes to grain.

I observed an experiment of this in rows of wheat that were all equally poor. One of the rows was increased so much as to produce more grains than ten of the others because it brought more of its stalks to grain, and its ears were bigger. These rows were drilled 12 inches apart and not hoed,

and were, by the shallowness and wetness of the soil, very poor in the spring. Then, by pouring urine to the bottom of one of the rows, that row was vastly increased above the rest.

Whatever Varro means by saying that the ears remain fifteen days in vaginis, it is plain that the ears are formed with the stalks and will be large or small in proportion to the nourishment given to them by the plant. Feeding the plants will cause the plants to produce large and plump grains. The best way to feed plants is through hoeing, especially hoeing right after the wheat has gone out of the blossom. Hoed grains weigh double the weight of the same number of unhoed grains.

By increasing the number of stalks, bringing more of them to ear, making the ears larger and the grains plumper and more full of flour, my hoeing method makes a greater crop from one tenth the plants than the common method can.

All these advantages will be lost by those drillers who do not overcome the unreasonable prejudices of the unexperienced concerning the width of the aisles.

Improve wheat yields: increase number of ears on each stalk

The same plant that, when poor, sends out but 2 or 3 tillers would, if well nourished by the hoe, send up a multitude of tillers as is seen by comparing hoed wheat with wheat that has not been hoed. Mr. Houghton reports 80 ears on a single plant of wheat, but a greater number has been reported by others. Mr. Houghton's 80 tillers are estimated to have 50 grains each, making an increase of 4,000 grains to one, but I have never found above 40 ears on a single plant on my fields. But there is no doubt that every plant would produce as many grains as Mr. Houghton's if they had the same nourishment that Mr. Houghton's had. I have measured sometimes 400 ears in a yard, though I did not weigh them: these were the product of 250 grains, some of them quite small.

I have numbered 109 grains in one ear of my hoed grey cone wheat, and one ear of my hoed lammas wheathas been measured to be 8 inches long (which is double the length of wheat grown in the common method). I have some of these ears now by me, and they are almost big enough to be a rarity. Indeed, it is not every year that they grow to that length, and when they do it is only when the plants have grown singly without any competition. But there is no year that one ear of my hoed wheat does not weigh at least twice as heavy as the wheat sown in the common method, taking a sheaf of either at random.

Land rents are high, use more of the hard-bought soil by keeping aisles

With wide aisles, you can raise a good crop with less labor, less seed, no manure, no fallow...but not without a competent quantity of soil (which is the least expensive thing given to wheat). The soil is of a whole good acre but about the tenth part of the common expense (and on poor land, less than a twentieth part), which I estimate at 5 shillings and 6 pence per acre. And, with my method, the crop enjoys more of this hard-bought soil than in the common method, for between the last hoeing and harvest, there remains nothing but empty space in the aisles!

Wide aisles reduce soil depletion

With 60 inch aisles, it is not necessary that you keep the roots from eating all the soil, if the wheat is the proper kind. The wheat will always leave sufficient pasture for the succeeding crop

because it is impossible for them to come into contact with all the soil in one year. But the more pasture that is made for them by frequent hoeing, the more will be left unexhausted.

The objection that aisles are "lost" land because they yield nothing is false: the aisles are being used by the roots to allow each plant to yield more. The farmer who would spend money to buy fertilizers should have no objection to spending money on land rent to increase their crop yields

It is an objection that nothing is planted in the aisles: the land is called "lost" because it yields nothing. But I have plainly proved that the roots of the cone wheat reach the soil in the aisles, traveling more than three feet through another row when the wheat was only half grown.

Farmers do not grudge to spend 3 or 4 Pounds in the buying and carriage of manure for an acre, but somehow think themselves undone if they spend the extraordinary 18 penny's worth of soil per acre on wide aisles. Consider that the aisles will allow a greater yield than the manure, consider that tillage is the best and cheapest entertainment that can be provided to plants! Compute it even not just as a portion of the rent, but as a savings equal to an 11th part of the usual expenses per acre and tillage results in higher yields at less cost than manure (even if you have more or less than 11 rows per acre, tilling in the aisles still reduces expense and increases revenue).

The horse hoe well applied will provide the services that manure or fallow usually do, but it cannot make more soil. If the aisles are narrow, all the soil in the aisle is used to make the beds and there is too little left to be pulverized. Then, with those narrow aisles, you must resort to manure and fallow and all kinds of exorbitant expenses. Do not object to wide aisles: spending a penny's worth (or two penny's worth!) of soil in each row (worth only a few groats per acre) for wide aisles sees the return of Pounds in succeeding crops.

Wheat before harvest, standing in rows with wide aisles between them may not seem to the eye to equal half the bigness of wheat dispersed all over the land when sown in the common manner. And yet there is more deceit in the appearance of those difference crops when they are young and grass: just as the sun and moon appear to the eye to be larger when near the horizon, so too is this an optical illusion. We should not compare by our imagination, but by reason. Imagination often deceives us by false or precarious arguments, but reason leads us to demonstration by weights and measures. Prejudice will vanish at harvest upon the weighing of the crops: even though all those wide aisles were bare, the hoed wheat will make a finer appearance than the wheat grown in the common method. Look upon your field across the rows, and though you won't see the aisles, you will see a fine crop!

Land kept with well hoed aisles never needs summer fallow

8 acres, part of a land of 20 acres, were drilled with aisles of 42 inches and brought a crop, but the second year, the 8 acres were not hoed and the crop was poor. The third crop made the land so foul and turfy that it was forced to lie in summer fallow: there was no way to bring it into tilth except through summer plowing. The remaining 12 acres had been kept with wide aisles and was constantly hoed, and remained in good tilth, never failing to yield a good crop. This narrowness of the aisles, if the damage of it is rightly computed, would amount in half the inheritance of the land and was occasioned by the willfulness of my bailiff who, tilling it on the level, ordered the horse to

be guided half a yard within the mark because he fancied the aisles were too wide if he followed my directions.

Hoeing makes soil deeper, plants eat soil

In a field there is now the sixth crop of wheat in wide aisles that is performing very well, though the ground has had no kind of manure for any of the six crops, or for years before the first was planted. Last year's crop was the best of the five previous, this year's promises to be better than last.

In the first five years, the hoe went deeper in some areas and shallower in others. In the deeper areas, the plow and hoe plow raised more pasture, but less in the shallow. By the fifth year, the land became of equal depth, and the plow and hoe plow went deeper.

If you ask from where the soil came when there is always vegetable matter carried off by these constant crops of wheat, Mr. Bradley and his "correspondent" would give the very ready answer by saying that "Vegetables are Nourish'd by Air; and that the Earth serves for little else, than to keep them fix'd and steady; therefore the Wheat receiving its Augment from the Air, could not consume any part of the Earth." This would be an easy and good answer—if it were true!

While Mr. Bradley misunderstands that plants eat soil, Mr. Bradley is correct in saying that the soil is supplied by the atmosphere. The soil that the rain brings can feed the plants alone (if it falls in great quantity), for it is plain that the soil that nourished Helmont's tree was supplied by the water that it was given and not by the dews (the box prevented the dews from entering). Dews, though, add very much to the land. Thus, continually tilled and hoed land, which receives more dews than untilled and unhoed land, would receive more soil. Dews, when kept in a vessel long enough to evaporate, will leave a greater quantity of black matter at the bottom than rain water does.

I suppose that dews are exhaled from rivers, moist lands and the exhalations of plants. Most of the dew that falls on land and plants is immediately exhaled again, unless that land has been well tilled or hoed. By this means, the untilled land helps to enrich and augment the tilled land, contrary to Virgil's doctrine of "tillage kills soil[228]." If an acre is tilled two years together without sowing, it becomes richer by the tillage than lying unplowed and fallow for 4 years, (this may be proved by experience).[229]

But then, as to rain, the seas being larger than all the land (and by their motion becoming replete with terrestrial matter) it is not unlikely that more vapour is raised from one acre of sea than from a hundred acres of land. It is very probable that islands are continually gaining from the deep, by means of rain, that soil which the ocean's vapors produces.

Some have been so curious as to compute the quantity of rain that falls yearly in some places of England by a contrivance of a vessel to receive it. It has been found that in one of the driest places very far from the sea that 14 inches of rain falls during a year. In other places, much more falls (in

[228] *Neo nulla interea est inaratae gratia terrae.* Translation by Aaron Brachfeld.

[229] We think of Columella here: *Non igitur Fatigatione, quemadmodum lurimi crediderunt, nec senio, sec nostra scrilicet ineria minus benigne nobis arva respondent* [It is not because of weariness or old age that our cultivated lands yield us a less than generous return, but because of our own lack of unresponsiveness .] – Columella Lib. II, Cap. I. (Translation by Aaron Brachfeld).

Paris, more than 19 inches of rain falls, and in Lancashire Mr. Townley found, by a long continued series of observations, that more than 40 inches of water falls in a year!).

Should we as easily compute the true quantity of soil in rain water, as the quantity of water is computed, we might perhaps find the quantity of soil that falls to feed our hoed wheat.

But if land is sown with wheat and not hoed, its surface is soon encrusted and then much of the water, with all its nutritious contents, runs off and returns to the sea without entering the ground; then, in summer, a great deal of what moisture remains is exhaled by the sun and raised by the wind.

The objection that tillage raises weeds is false: hoeing kills weeds that are raised up by tillage

There are some who think it a fatal objection that the more an aisle is hoed, the more weeds will grow in it and that the hoe can produce or (as they say in their words) "breed" in it as many weeds in one summer as would have naturally arisen in ten years by the common method. But in this objection they forget that the hoe can destroy as many weeds in one summer as the common method can in ten years!

And, I might add, that since the new method kills weeds before they seed and very few of the weeds in the old method are killed before they seeds are ripe and shed, these objectors must allow that the new method lessens a stock of weeds more in one summer than theirs can do until the world's end...unless they believe in the spontaneous generation of weeds (to which opinion nothing is more absurd).

Objections to Jethro Tull's statistical sampling methods unfounded

Some object against my method of weighing a yard or a perch in length of a row saying, "this does not determine the Produce of a whole Field."[230] I answer that they judge my methods correctly if the produce of the whole field was not of equal goodness. But the entire field is of similar goodness: if it were not, it is because one part of the field is richer or differently managed from the other part. The same causes that produce 20 ounces of clean wheat upon one yard will produce the same quantity upon every yard of a million acres!

When the crop of half a field is spoiled by sheep and not hoed at all (or hoed improperly), it is ridiculous to compute the whole field together in an experiment. However, we might weigh the poorest part and the richest part to prove the difference from one to the other, or weigh only the poorest to see how poor of a crop we can raise (which is sometimes a good trial to undertake).

I have designed my experiments to assess how good of a crop I can raise with less than 10% of the normal expenses and designed my experiments well. I weigh the produce of the same quantity of ground, and include samples of the best and the worst. I allow 2 square yards of the usual method to every I yard in length of my treble row. I have trialed all kinds of wheat – the best and the worst – but I have never found that best of the usual method equals the best of my drilled method. Indeed, these high yields I report have not been earned on the richest land in our country. Indeed, I am sorry to say that the farm whereon I practiced horse hoeing, being situated upon a hill that consists of chalk on one side and heath-ground on the other, has usually been noted as being the poorest and shallowest soil in the entire neighborhood.

[230] Even good statistical analysis today still meets with similar objection! –A.B. & M.C.

48 bushels per acre yield may be easily expected

A yard in length of my treble row of the third successive crop of wheat, without manure or fallow, produced 20 ounces of wheat which, allowing six feet to the aisles, is about 48 bushels to the acre. This, allowing 7 inches between rows and 2 inches between the outside rows and the aisle, is 18 inches in a treble row. Now, if in the old method, the crop was as good all over the ground as it was in these 18 inches of the treble row, they must have 192 bushels to the acre (which they do not!).

No, farmers that practice the old method, though they manure as much as they can, can scarcely raise 24 gallons (about 2.52 bushels) by the third year on an acre of land of equal goodness to my treble row.

The mean price of wheat (between dear and cheap) is about 5 shillings to a bushel. Therefore an acre that would produce every year 8 bushels without any expense more than the seed itself would be thought extraordinarily profitable. A drilled acre that produces 16 bushels of wheat with the expense of 10 or 15 shillings is more than three times profitable than the acre with no expense that would yield 8 bushels...and I have not had an acre yet that was tolerably well managed that produced much more than 16 bushels per acre!

STORING AND SELLING WHEAT TO TAKE ADVANTAGE OF CHANGES IN MARKET PRICES

It is commonly said that a farmer cannot thrive if their wheat is sold for less than 5 shillings per bushel, and so farmers are obliged to keep the wheat until the price improves beyond 5 shillings per bushel. To keep the wheat until the price improves, the farmer will keep it in the straw, and use the best contrivances to protect it from the mice.

The most secure way of keeping a great quantity of wheat is to dry it. When I lived in Oxfordshire, one of my nearest neighbors was an expert at this, having practiced it for the greater part of his life. When wheat was under 3 shillings per bushel, he bought in the markets as much wheat as his money would purchase. He often told me that his method was to dry it upon a hair-cloth in a malt-kiln with no other fuel than clean wheat straw, never suffering it to have any stronger heat than that of sunshine on a warm day. The longest time he ever let it remain in this heat was 12 hours, and the shortest time was about 4 hours (the damper the wheat was, the longer he kept it in the heat because the more drying it required). But how to distinguish nicely the degree of dampness and the number of hours proper for its heating in the kiln he said was an art that was impossible to be learned except by practice.

About 23 or 24 years ago, wheat being at 12 shillings per bushel, he had in his granaries 40,000 bushels of dried wheat, none of which cost him more than 3 shillings a bushel!

This dried wheat was esteemed by the London bakers to work better than any new wheat that the markets afforded. His speculation that put him on this project was that it was only the superfluous moisture of the grain that caused its spoilage and made it liable to be eaten by the wevil. He thought that if the moisture was dried out, the wheat could be kept sweet and good for many years and then thought that the drying effect of heat would not change if provided by the sun or by a kiln.

As proof of his postulation, he would show that every grain of his wheat would grow after being kept 7 years.

He was a most sincere and honest Yeoman who, from the small substance he began with, left behind him at his death an inheritance of more than 40,000 Pounds – the greatest part was acquired by his drying method.

Jethro Tull's Supplement

Importance of ridges to winter wheat: it is the only food of the seedling. Thus, ridges must be plowed fine and deep; caution urged against treachery of hired plowmen who believe roots only extend a few inches into the soil

It is the depth and fineness of a ridge that the success of our crop depends upon, the plants having nothing else to maintain them during the first six months. And, if for want of sustenance they are weak in the spring, it will be more difficult to make them recover their strength afterwards enough to bring them to their due perfection.

But plowmen have found a trick to disappoint us in this fundamental part of our husbandry, if they are not narrowly watched; they do it in the following manner: they contrive to leave the trench very shallow, and then in turning the two first furrows of the ridge, they hold the plough towards the left, which raises up the fin of the share, and leaves so much other earth where on the rows are to sand whole and unploughed that after once harrowing there does not remain above two or three inches in depth of fine earth underneath the rows when drilled, instead of ten or twelve inches.

On a time, when my diseases permitted me to go into the wheat field where my plows were at work, I discovered this trick, and ventured to ask my chief plowman (or rather chief master) his reason for doing this in my absence, contrary to my direction? He magisterially answered, according to his own (and Equivocus's) theory, which servants judge ought to be followed before that of him they call master, saying, that as the roots of wheat never reached more than two or three inches deep, there was no need that the fine mould should be any deeper. But those shallow ridges, which were indeed too many, producing a crop much inferior to the contiguous deep ridges, showed, at my cost, the mistake of my cunning plowman.

It is true, that people who examine wheat-roots when dead, are apt to fall into this mistake; for when they are shrivelled up, and so rotten, that they break off very near to the stalk in pulling up; but if they are examined in their vigour at summer, with care, in a friable soil, they may be seen to descend as deep as the fine pulverized mould reaches, though that should be a foot in thickness.

I took up a wheat ear in harvest that had lain on the grass in wet weather, where the wind could not come to dry it, which had sent out white roots like the teeth of a comb, some of them three inches long. None of the roots having reached the ground, they could not be nourished from anything but the grains, which remained fast to the ear and had not as yet sent out any blade. It is unreasonable to imagine that such a single root as one of these, when in the earth, from whence it must maintain a pretty large plant all or most part of the winter, should descend no farther than when it was itself maintained from the flour of the grain only.

Varieties of wheat

[231]It is said to grow mostly in some islands of the Archipelago, and some author describes it Triticum spica multiplici. There is another sort of wheat that has many little ears coming out of the two sides of the main ear; but this is very late ripe, and doth not succeed well here, nor is it liked by them who have sown it; yet I have had some ears of it by chance among my drilled wheat, which may have been larger than those of any common sort. I have not as yet been able to procure any of the Smyrna wheat, which I look upon as a great misfortune: but I had some of it about forty years ago.

Good management of labor is important: lack of skill and lack of will are two different things; the bad labor laws fail to prevent abuses by laborers against their employers

That which is ill done, I reckon as not done: want of skill and want of will are much the same thing. My agriculture having been carried on by common laborers without anybody to inspect them (except when my disease suffered me to attend them, which for several years last past has been very seldom), cannot be expected to be all well managed, for though they can do it well when they please, yet their will being above control I must be content with their doing some tolerably well every year.

But perhaps it may be asked why I do not carry on my new husbandry by house servants? This indeed might be a proper question in other countries but it is not here; for husbandry servants of all sorts have now attained to such a thorough knowledge of their own arbitrary power given them over their masters by our new laws that I would not keep plowmen in my house though it were to cost me more than it would to buy a new farm yearly...Especially since the famous judgement given publicly by some country magistrates that encourages the most disorderly servants against fear of punishment for the most enormous crimes they can commit against their masters. It is not proper for me to report this case, in regard to the respect I bear to all magistrates, and in those four (which were the number) in particular. Nor will I believe there was either party or prejudice in it, whatever may have been by many of the hearers on that trial insinuated.

For my own part, I always chose to suffer under my laborers (and house-servants too, when I formerly kept them) rather than to suffer more by complaining as my neighbors generally did. Thus no magistrate ever had any trouble upon my account.

Besides, my diseases now prevent my complaining, though I should have hopes of redress, and will not permit me to travel so far as to the nearest magistrate; and he who sends one servant to complain of another is likely to make but little of his cause: or what adequate satisfaction can be had for the greatest damage done to the master by the servant, who takes care, by spending all his exorbitant wages, as most of them do, not to be worth a farthing?

There are also other objections, peculiar to my case, against house-servants. One is, that they have made it a custom to leave their service whenever they please, which is commonly at spring of the year, when they are by farmers reckoned not to have earned more than their diet; for then they must have half a year's wages from Michaelmas, and afterwards they can, in another service, have almost a whole year's wages for the remaining summer half year; if you will not consent to let them go, and comply with such terms, they will make them much worse by spoiling or killing your cattle, or by other private devices, in which they are better skilled than in their proper business.

[231] This fragment is presented as found –A.B. & M.C.

But this is only a misfortune common to English agriculture[232]; but what is peculiar to my scheme is, that when servants go away, I must be continually teaching new ones, when I can find them, both which my confinement and want of health make difficult.

This objection is not quite so strong against day laborers because they are paid by the week, and being settled, married men, have not so much choice of services as the singled, unsettled have.

Upon these accounts the day-men do not impose so hard terms as the other. When I have taught them my scheme, they will continue to work for me as long as my service is more beneficial to them than any other they can get; and as long as I will forbear to find much fault with what they do, or at least forbear to speak of them of their faults otherwise than in a very humble, persuasive manner. With these terms I would gladly comply, if it were only to purchase that peace and quiet which are necessary to my infirmities, and incompatible with keeping ploughmen in my house.

This precarious condition we are in as to hands, under the present regulation is very discouraging to every new scheme that requires labour; but the thing that is most detrimental to perpetual crops of wheat is the deceit and idleness of the weeders, that are necessary to cleanse the partitions and rows from weeds, by hoes, or hands, or both, especially after they have been a year or two neglected. The shattered seed, in that case, overstocks the ground.

These weeders are the same sort of people that Mr. Duck describes as haymakers, their tongues are much nimbler than their hands and unless the owner, or some person who faithfully represents him (but such a person is hard to be found) works constantly amongst them, they will get their heads together half-a-dozen ion a cluster, regarding their prattle more than the weeds. A great part of their time they spend in play, except a few of them who bring their own work with them, some their sewing, some their knitting, and these must be paid for doing their own work upon my land. This wrong I have seen done both to myself and my neighbours and it has put me upon endeavouring to find a way of disappointing the weeders[233] by planning wheat sometimes upon a fallow without dung for one crop only.

This is done in the following manner: after a crop of barley sown upon the level had immediately succeeded several successive horse-hoed crops of wheat, this barley stubble was fallowed in the spring, tilled in the summer, and after St. Michael ploughed up into ridges of different sizes, none under four feet, nor any above five feet; then drilled with white cone-wheat in triple rows by my usual wheat drill, having its marking-wheels set nearer together according to the different sizes of the ridges. The partitions not being infested with weeds, no weeders were employed thereon, but the intervals were horse-hoed. The crop of wheat was good, it appeared like a sown crop in thickness at top before it was reaped, except that the ears were much larger, and there were few under ears. It was indeed on some of my best land, but has had no dung or manure since the year 1720, and this crop was in the year 1734.

By this means the weeders were convinced that it was possible for me to make a shift to go on with my hoeing scheme without employing them, and they are brought now to better terms: to hoe the two partitions of the triple row, and also all the earth that is left by the hoe-plough on each side of the row, and to cleanse all the row from the weeds for the price of a penny a score, (twenty

[232] Unfortunately not. In America, and many other places, things are similar... or worse. Sometimes those who are paid by the day or week will practice theft and other crime during their work (or after work, when there is less security to prevent them from doing what they would like to in the workplace they have recently become familiar with). –A.B. & M.C.

[233] His weeders would be better disappointed by a modern mechanical cultivator, described in subsequent chapters. –A.B. & M.C.

perches in the length of a row, which in the six-feet ridges amounts to one shilling and ten pence per acre).

At this price they earn almost double the common wages and yet, if they work by the day, it will cost me double of these price to have it worse done, so great a difference there is between their working for me and working for themselves. The weeders generally are women and boys, and even these sometimes earn men's wages, so that I have plenty of them, and choice; for they make an interest to be employed. It is only necessary for me to take care that they do their work well, and oblige them in the bargain to amend what they do amiss; and for that end, the rows that each person or company undertake are separately known. I give them the same price for oats and barley as for wheat, and the same for double rows as for triple; because as the former are less troublesome they hoe them the deeper.

They use for this work hoes of four inches breadth, very thin and well steeled; their thinness keeps them from wearing to a thick edge, and prevents the necessity of often grinding them. Such hoes are in use with some gardeners near London. They need not being afraid of drawing these little hoes across the rows of young wheat to take out the few weeds that come therein at the early hoeing, for while the wheat-plants are small it may be an advantage to cut out some of the weakest, as they do of turnips, for I perceive there are oftener too many pants than too few.

But the thing that causes the greatest trouble in cleansing the rows, is when the seed is foul, (i.e. full of seeds of weeds), therefore I cleanse my seed-wheat by drawing it on a cloth on a table, which makes it perfectly clean.

This hand hoeing should be performed about the end of March or beginning of April, before the wheat is spindled (i.e. run up to stalks), and if the weather is dry enough, you may go lengthways of the rides with a very light roller to break the clods of the partitions, whereby the hoe will work the better.

If there should afterwards more weeds come up, they must not be suffered to ripen if the soil will be every year freer from weeds.

And the expense of this hand-work on the rows would be well answered if there should not be one weed in them, and so it would be, if a second hand-hoeing were bestowed on the partitions of every crop of wheat not suspected of being too luxuriant.

If after the last horse-hoeing there should be occasion for another hoeing of the intervals where the narrowness of them and the leaning of tall wheat makes it difficult or dangerous to be performed by the hoe plough, a slight shallow hoeing may be performed therein by the hand-hoe with ease and safety, and at a very small expense, which would be more than doubly repaid in the following crops.

Equivocus falsely describes the fertility of Tull's farm

I am sorry that this farm, whereon I have only practiced horse-hoeing, being situate upon a hill that consists of chalk upon one side, and heath-ground on the other, has been usually noted for the poorest and shallowest soil in the neighborhood.

In contradiction to this description, Equivocus, in p. 31 of his Essay for July, describes it as follows: "We know the author's farm, called prosperous, is a rich soil, and lies on a flat, which retains moisture more than up-land declining ground (especially sandy or gravely) will."

Which of these two opposite repugnant descriptions is true cannot be difficult to determine.

As to its lying upon a flat contrary to a hill, it is both known and seem to be one of the highest farms in all that part of the country of Berks where it lies; it may be seen at ten or twelve miles distance, and was a more remarkable eminence before the trees were blown down by that memorable storm in the year 1703.

The bulk of the land belonging to the farm is, on the south side, for near a mile in length, always called Bitham Hills, and are, for the most part, declining grounds on a chalk: in dry weather the whole staple looks of a white colour, it is full of small flints and smaller chalk-stones: below these hills is a bottom, where are some grounds upon a chalk also, but had not then been used in hoeing, having lain with Sanfoin thirteen or fourteen years. On the west side all the land is called East Hills, being on the east of the farms to which they all formerly belonged. On the north-west side is a high field, called Cook's Hill, and is the only field of my farm that is not upon chalk. It is a very wet spewy soil of very little value, until I made it dry by ploughing across the descent of the hill. Everybody knows that chalk is not apt to retain moisture; and as to the richness of the soil of my farm, if Equivocus could make that out to be true, I could easily forgive all the other falsities of his description, though it is scarce possible that any thing can be more false.

The soil is all too light and shallow to produce a tolerable crop of beans.

This farm was made out of the skirts of others; a great part of the land was formerly a sheep down; and whilst the whole was kept in the Virgilian management (usual for such land) it had the full reputation of poverty. The highest part of it used to be sown (as I have been well informed) with oats once in two or three years upon the back, and if the summer proved dry, the crop was not worth the expense of that once plowing. The generality of farmers were then of opinion, that if this should be thoroughly tilled and pulverized, it would become so light that the wind would blow the staple away; but the contrary happened, for it being ploughed five times instead of once, it produced good barley and other corn, and never has returned to its former degree of lightness since, and this was above fifty years ago. And now tillage and foreign grasses are come into fashion, enclosed lands, which do not rot sheep, (as not one foot of mine is wet enough or rich enough to do), are become of greater value than formerly. And besides they allow that my farm is one-third better for a tenant than when I took it in hand, and yet I should be glad to let it for half the rent that rich land is let for.

Should Equivocius tell a person who never was at London that the monument stands in Smithfield, or that London-bridge is upon Holborn-hill, it would not be more notoriously false than his description of my far is.

And that no part of the true description of that odious crime (the plain term for which ought not to be given by or to an Englishman, except one as vile as Equivocus) might be wanting; he, for the collective body of his Society, pronounces in the plural number, "We know," &c. So that it is not ignorantly, but wilfully committed, by endeavouring to impose upon the world, for a truth, what they know to be false, with intent to deceive.

He seems to have written his false description of my farm for no other end than to accuse me of that very crime of which he himself is, in this relation of his, indisputably guilty; for if the nature and situation of my land had been as he says, it would have made nothing for his purpose in any other respect.

That society, by publishing this and many other notorious falsehoods seems fond of being publicly known to be infamous authors of no veracity, and not to be credited by any body who is not willing to be deceived; but pity it is their particular members should lose their merited renown, for want of a proper list of names and additions.

Supplement of the Fifth Edition:

Spring Wheat

We do not plant winter wheat, but only spring wheat: it is better for the ecology, as it does not require the tillage of the previous year's debris in the winter.

In the Spring 2004 journal of the Royal Society for the Protection of Birds (RSPB), Mike Shrubb writes in his *Birds and Combines, Bird Life and Agricultural Change* about how a transition to winter wheat from spring wheat impacted the local ecology around his farm. Equally dangerous to the animal life was the transition to tractors, and other mechanization. "I have been observing interactions between farming and birds since the late 1950's, mainly on the family farm (of 600 acres) in West Sussex but most recently also in Breaconshire. Our farm was a true mixed farm when I was a schoolboy: we grew wheat, barley, oats, turnips, Swedes, sugar beet, mangolds, linseed, clover and sometimes beans. There were two flocks of sheep and a large area of damp pasture grazed in summer by beef cattle. We used both horses (until 1952) and tractors, corn was cut with a binder, ricked and threshed during autumn and winter. I grew up with a farming system that developed in the late 18th and early 19th centuries and persisted until 1950."

Shrubb goes on to explain that since the 1950's, farms have specialized. His own farm has no more livestock, and only grows winter cereals and rape; the grass is largely permanently set-aside, the rest plowed or sold off. "Farming does not and never has 'preserved the countryside' in the sense of maintaining particular habits and environments. It is a catalyst for change. A revolution in farming methods and economics brought enormous changes to both landscapes and habitats after 1750. It was said that money drove arable farming into increasingly marginal areas in the 19th Century and that was the same in the 20th Century. Such expansion has long been at the taxpayers' and consumers' expense, though tax incentives (18th and 19th Century Corn Laws) or subsidy. With the loss of such support, farming withdraws. But the habitats do not revert to their original form: enclosures, the new system of 'high farming' that followed, recession and the recent farming revolution all produced profound changes in the landscape to which wildlife had to adapt."

The difference between the 19th Century "high farming" and the modern farming, according to Shrubb, is that the high farming created a diverse countryside with a varied farmland landcape. This encouraged wildlife, especially birds. Dr. Lovelock (author of the Gaia hypothesis) agrees. The high farming presented, with its hedges and diverse fields of crops, something of an improvement to the local ecology: the plant life was healthier, and there was a balance between true wild spaces and weed-free cultivated ones. "The retention of the old grassland habitats was one reason why changes in the 19th Century had surprisingly little impact on brids," says Shrubb, "even at the height of high farming, livestock densities were quite low and sheep were as much a part of the arable system as the pastoral one. In the modern era, birds of the pastoral system – the grazing land – have come under even greater pressure than those of the arable fields, because of radical changes in habitat, management and stocking patterns." Grasslands are now plowed and reseeded, pesticides have destroyed insect life, and wetlands have been drained. In short, while the diversity of the land has diminished, the balance between the wilderness and farmed lands has also become imbalanced.

This itself could lead to a disaster, but the chemicals used since the 1960's are damaging the wild spaces further. "The revolution in chemical weed control since the mid-1960's has led to the loss of the weeds of arable land and is steadily sapping the soil's seed bank. This is the key change in arable land. Selective weed control and the ability to use herbicides in autumn have permitted an

unprecedented change in the main season of cultivation, concentrating on autumn sowing instead of spring cultivation. This has led to the loss of winter stubbles and the loss of disturbed ground in spring, both of which were enormously valuable food sources for birds. Weed control in the 1940's had a swift impact on certain weeds such as charlock, but the herbicides could not be used in root or brassica crops and a number of weeds that produced seeds for birds were little affected," says Shrubb.

The loss of weeds in the field was little compared to the loss of weeds in the wild spaces when the chemicals drained into them. The food chain, collapsing under the loss, extended through the already pressured insects to the birds and larger wildlife: the birds relied on insects and weeds for survival.

The ricks invented by Tull served as food sources as well as shelter for many animals, and now that hay is baled and immediately hauled off to market (or left on the field in a bale), these resources are gone. The loss of winter green manures also reduced the shelter and food for many animals, both in seeds and insects. Nest sites in the fields were harassed or destroyed by those farmers undertaking autumn planting.

Shrubb concludes by saying that the area under cultivation impacts ecologies less than the way they are cultivated, and that government policies and laws are now required to protect the ecology upon which the farms depend. "Good dvice, monitoring and supervision can be provided. In the Netherlands, for example, dairy farmers are paid for the number of breeding waders they produce, rather than entering general environmental schemes, have been successful in increasing bird numbers because of the simple, clear, measurable objectives of the scheme. While we may be doing much better for cirl buntings, can find ways to increase the number of nesting skylarks and can recreate some habitats, such as wet grasslands, we are yet to do much for other species and habitats such as chalk downlands, which require the wholesale recreation of the old farm systems that created them. In general, in my view we still seem to be rather better at conserving rare and local birds than widespread ones." Shrubb's book, *Birds, Scythes and Combines: a History of Birds and Agricultual Change* is suggested further reading. The RSPB agrees with Shrubb, and points to the opportunity for farmland to "nurture" nature, though laments that the farming schemes praised by Shrubb are "gone forever."

We beg to offer hope to the RSPB, the old schemes earn better money than the new schemes, even with their subsidization, and with the help of publications like this book and the RSPB's journal, improvements can be made

Wheat Nutrition

Wheat is a nutritious food. The USDA has compiled a vast quantity of nutritional data on it for human consumption, and the amount of minerals and vitamins present are astounding. The wholesomeness of the whole grain is undisputed, but those who would feed wheat to livestock would be interested in several key nutrients. Citation for this table is found in the Chapter on Animal Husbandry.

Nutritional Values of Wheat

Macronutrients	Hard Red Spring	Hard Red Winter	Soft Red Winter
Calories (kcal/kg)	329	327	331
Moisture	12.76%	13.10%	12.17%
Crude Protein	15.4%	12.6%	10.4%
Fat	1.9%	1.5%	1.6%
Crude Fiber	12.20%	12.20%	12.50%
ADF	*	*	*
NDF	*	*	*
Minerals			
Calcium	0.62%	0.29%	0.27%
Phosphorus	0.04%	0.03%	0.03%
Iron	0.0360%	0.0390%	0.0321%
Zinc	0.0200%	0.0265%	0.0263%
Magnesium	0.32%	0.13%	0.13%
Manganese	0.0041%	0.0040%	0.0044%
Copper	0.0004%	0.0004%	0.0005%
Selenium	0.0071%	0.0071%	*
Potassium	0.34%	0.19%	0.40%
Cobalt	*	*	*
Sulfur	*	*	*
Vitamins			
Vitamin A, IU	9.00	9.00	*
Vitamin E, IU	1.30	1.30	1.30

CHAPTER TWELVE: OF BLIGHT

Ancients ascribed blight to divine intervention

The Ancients did not take notice that there were several kinds of blight, neither did they inquire after their causes. This lack of curiosity and observation prevented them from learning their causes and developing effective remedies against blight. They called it in general by the name of "rubigo" or "rust" for the likeness of the blighted straws and leaves to the color of rusty iron. They thought it came from the gods since they were ignorant of the natural causes.[234]

[234] Montesquieu would describe the natural laws that govern those "causes" which lead to blight as a manifestation of divine will, and through this perspective the science of agriculture is a process of learning the Almighty will through practice, of worshiping the Almighty through study. Learning the causes of rust allows a farmer to better understand what the laws of farming are, what the divine will is.

It was through this perspective that Columella wrote his great work (thousands of years before Montesquieu) *On Agriculture* in argument against those who would have used the punishment of the gods not as a means by which to improve themselves, but as an excuse for the destruction of the human spirit through aggressive war, Imperial domination and legal oppression.

Since the beginning, there have been those who would sow distrust between a people and the gods of their ancestors. Yet the sensible mind trusts the gods and laws of nature: to conquer this old hate it we must love and trust the gods of our ancestors as our ancestors did – we must further the breadth and depth of human understanding and power, we must improve the quality of life for all people. To vanquish war we must secure the liberty of the human spirit from fear.

Through a study of natural law we come to trust the benevolent nature of our gods. Columella's words, which motivated Tull's inquiry towards the "increase of bread" continue to serve lessons against those who would propose that the gods and nature present a kind of malevolent hatred. Columella teaches that the natural law is absolute, and that by obeying it we can prosper as surely as by disobeying it we can expect disaster: "*Again and again I hear the leaders of our State condemning as harmful to crops now the unfruitfulness of the soil, now the inclemency of the climate. And some I hear grounding these complaints on what is pretended to be well-founded reasoning on the argument that, in their opinion, the soil was worn out and exhausted by the over-production of earlier days and can no longer furnish sustenance to mortals with the benevolence of ancient times. I am convinced, Publius Silvinus, that this reasoning is very far from the Truth: it is a sin to suppose that Nature, endowed with Her perennial fertility by the Creator of the universe, could be affected with barrenness as though with some disease. It is unbecoming to a person of sound judgment to believe that the Earth – to whom was assigned divine and everlasting youth so She could be the common mother of all things (She has always brought forth all things and is destined to bring them forth continuously) has somehow grown old, as we mortals might. No, I do not believe that such misfortunes come upon us as a result of the fury of the elements, but rather because of our own fault. For when a venture turns out unsuccessfully through wrong management, one avoids the mistake that he had made, even as the instructions of a teacher cast a light upon the right course.*" –Book I.

Virgil prescribes no action against blight

Virgil, who was very sincere when he had no hopes of great gain by flattery, tells the common farmer in plain terms that if his grain is eaten with the blight, that there is no better advice than to comfort their hunger with wild acorns.

Palladius describes how to appease the gods to prevent or cure blight through prayer, sacrifice and threats; threatening the gods is generally useless. Discussion on the modern sorcerers Rudolph Steiner and Bill Mollison who prescribe a method of agriculture based on a mysticism of their own inventions

Though Virgil can prescribe no recipe to prevent the blight, Palladius (Lib. I, Tit. 35) recites many recipes against the blight (and other injuries) which were thought to come from the gods. The chief efficacy of them seems to consist in secret contrivances by which to conjure sympathies and antipathies with the clouds. And when prayers and sacrifices would not prevail with the clouds, the ancients proceeded to threats to scare them. They brandished bloody axes against the gods[235] as a summons to surrender or expect no quarter, but unless these peasants had better means than the Titans[236] in besieging heaven, it may be believed that their menaces were in vain.

They acted with their gods like some modern zealots do who take the same course with their Saints: when these modern zealots are weary of praying in vain to their images (which remain, for all the piety of their worshipers, so idle[237] or obstinate as to not procure what their votaries have a mind for them to), they think it is their place to bring their Saints into better manners by correction. Thus they fall from prayers to whipping their Saints in effigy.

Columella asks us witness and believe – for our own salvation and the salvation of our farms and our State – in the good will of the gods. In agriculture lies either the preservation or destruction of our mighty nation; the welfare of our State, the prosperity of our farms. To Columella, our love of Truth will secure our virtue, and give us the faith that our gods love us, and guide us through a darkness of lies towards harmony with all the gods. –A.B. & M.C.

[235] "Cruentae secures contra calum minaciter levantur" [translation by Jethro Tull].

[236] Though Tull uses the word "Giants" correctly, "Titans" is a word that is more general today. –A.B. & M.C.

[237] Idle - Idol, a word play. By now you may have observed that, though at times Tull is bluntly harsh at times, there are times with he manages to restrain himself. It is an insight into the mind and beliefs of Jethro Tull that he would sometimes attack someone for being an idol worshiper and other times not, or directly criticize a person's religious beliefs sometimes and not others. By looking at where Tull picks fights and where he tolerates differences, it becomes apparent that Tull places blame for the ills of humanity on those who work against Truth, and believed – as all enlightened scientists ought to – that a courageous pursuit of Truth would find the end of war and want, and the beginning of a new age of prosperity and friendship for all people. It is the same enlightened attitude that allows him to forgive his contemporaries and the ancients for their idol worshiping and other "arrogance" – so long as their intention was to illuminate Truth (an intention the flattering and entertaining Virgil and the unnamed idol/saint whippers never had, but that the idolater Columella did have). Tull is ready to forgive all other sins if the sinner is a humble servant of Truth. –A.B. & M.C.

Yet even whipping Saints in effigy and other arrogance will not cure the blight any better than brandishing bloody axes against the gods!

Palladius thought, as many of the ancients did, that Heaven was to be frightened from spoiling the fruits of the field and garden with red cloth, the feathers or the heart of an owl, and a multitude of ridiculous scare crows. The ancients, having no rational, logical, scientific principles of agriculture, placed their chief confidence in magical charms and enchantments[238]. Those who have

[238] In modern days, those without science or learning continue to rely on sorcery. Two modern sorcerers, Bill Mollison and Rudolf Steiner, developed an entire system by which a farmer can avoid the wrath of the heavenly gods and natural forces. Their mysticism is not of a very different sort than that of the ancients. Both prescribe various sacrifices (of oxen, gophers, mice and other creatures) or the application of holy water (or water infused with the "essence" of some protecting herb, rock or some natural force) to balance their field's "energy" or native spirits. Like any witchdoctor, they explain that the reason why these cures fail is because of a misalignment of the stars or the mischief of some unknown malevolent spirit.

Mollison and Steiner are quick to disclaim themselves when they direct the farmer towards insane actions: should the correct astrological time not actually be convenient or correct to the farmer (if, for example, the farmer is directed to plant seed at 3 AM or in the dark of winter), they tell the farmer to do what they would normally do (in example, planting at 3 AM can be moved to a more convenient time, or planting in January can be postponed even months later).

Would you believe they even give dietary advice based on the sublime alignment of the stars? To these mystics, the gods and natural laws can be controlled to perfection and from their writings you may learn not only by which stars to plant your root crops but which day is best to plant carrots; not only how to organize your home to prevent dissonance between Mars and Venus, but even how to correct the alignment of your toilet with Uranus!

And it is exactly this backwards way of doing things that leads them to ignore true laws of nature, and attempt to change the laws of nature to fit their own impressions of how things should be. The magic of Mollison and Steiner is no more subtle than that of the ancient magicians: to the ancient magicians, the stars and natural powers were deities that could be influenced by prayer or threats. Though Steiner and Mollison see them as non-living, passive forces upon life on Earth, they believe that the passive forces can be somehow harnessed as an engine of success. Yet, instead of undertaking a logical and reasonable observation of the causes and effects these passive forces have upon agriculture or human life (and discovering that, in fact, the stars effect things not at all), they abandon science and proceed to define the workings of the universe according to their own imagination and conception of how things should be.

This supreme rebellion against reality is a rebellion against truth, against nature and against God. Their nonsense ignores the principles of logical or reasonable cause and effect; to understand them you must give up what grasp of reality you have gained through experience and wade through an ocean of metaphysics and mysticism, trusting them entirely to be your guide. The price they charge for safe journey across the ocean of their making to the wilderness of insanity? If you are lucky, you lose only your crops; if you are foolish, you also pay the fees of tuition to learn from their unhappy students.

Perhaps you think we are too hard on Mollison or Steiner? Certainly we are not. Like Dr. Warkentin's work and the work of so many others, their arrogance (made all the worse by their ignorance and authority) warrants much more rebuke than we can give here. It would indeed be difficult to be too hard on these unhappy knaves that actively work to obscure Truth. They claim

the curiosity and patience may read of them in Virgil, Cato, Varro and even Columella (as fulsome as any of them!), all written in very fine language (which, I freely admit, is not all the erudition that can be acquired from the Greek and Latin writers of agriculture in verse and prose).

their system imitates nature when it subdues and conquers it, bending it to the will of their frail human mind and destroying its ability to self-sustain production; they claim to teach learning when their suppression of experimentation and study extinguishes the bright flame of the human spirit's love for the gods of their ancestors, robbing the student not only of their farm's inheritance but of their very birthright!

Science teaches much more than a knowledge of the world: those who would learn science also learn the virtues of patience and hope, an understanding that the gods are never malevolent, that if our crops fail, it is because we have, instead obeying the gods (our true teachers, who charge no fees of tuition!), stood arrogantly before them to set forth our own world order. Science teaches us to observe cause and effect, to learn and improve – to keep our eyes downward towards the soil into which we dig deeply instead of nervously behind us at old Saturn's sickle; to allow the moon, stars and sun to illuminate our work and thoughts instead of direct them. Science teaches us the will of the Almighty by allowing us to accurately understand the punishments and rewards that lay before us after our choices are made: we must seek our own enrichment and our own betterment if we seek the wellbeing of all creatures and wish to worship the deity whose act of creation we love. The gods reward good students and faithful servants as much as they punish wicked, scheming servants (who would enslave their masters!) and the students too stubborn to learn the lessons presented plainly to them.

Sorcery – which is rooted in that arrogant belief that the will of the gods may be influenced by human action – never saves crops so well as an application of science, and is an ugly, unlucky wickedness whose bitter philosophy yields only misery to those who would adopt it. Who would seek power over the gods, over nature, over another human being? Who dares to enslave the will of another creature – or their creator – to their own? A sorcerer or slaveholder is an enemy to all God-loving farmers, an abomination to all humanity. Farmers do best when seeking Truth and an understanding of the will of their gods, when every waking moment is spent learning from their teachers and strengthening themselves to undertake the tasks commanded to them. It is a gift to be free, and an abomination to enslave a creature – or your creator – to your will, taking the gift you prize so highly from someone else.

Be warned: when a sorcerer fails, the sorcerer is left penniless, hopeless and godless...utterly wretched. When a scientist fails, the scientist is left with the real hope that comes from knowing what went wrong and how to fix it, with the good will of their gods to do better the next time, and with the divine, Herculean flame of human spirit that gives them the strength to improve their capacity for greatness. Failure strengthens the humble scientist and destroys the proud and rebellious sorcerer. It is not for nothing that Columella advises that "soothsayers and witches – two sets of people that bring ignorant minds through false superstition to shameful practices" must never be admitted to the farm. –A.B. & M.C.

Blight strikes wheat in two seasons: when in the blossom and when the grains are brought to maturity

Wheat is blighted at two seasons: first, when in the blossom (preventing the generation of grain, leaving many of the husks empty in the ear because the seed has not been impregnated[239]). Second, when the grains are brought to maturity and become light and of little value for making of bread because they are not well filled with flour.

Little to be done to cure blight in the blossom

The first cannot happen in England before the frost because winters do not suffer the wheat to grow so much as to come into blossom until the month of June. But long continual rains will rot or chill the blossoms and prevent their fertility. No, this seldom happens to any great degree in England and we are happy that it does not – because our modern credulity is not strong enough to rely on the remedies prescribed by the ancients (and there are no other remedies against this type of blight).

Much to be done to prevent blight in the blossom: wide rows, wide aisles to increase air flow and increase evaporation; choose resistant varieties or those with short beards

Don't despair: though there is little you can do to heal the damage of this blight, there is action to be taken to prevent this blight. Wheat that grows in open fields has some advantages from the drying wind (which also dislodges the water from the ears sooner than in sheltered places), and planting in wide rows with wide aisles keeps the ears dry. Some varieties are more resistant to the water than others: the lammas wheat does not hold drops of rain so long as bearded (or cone) wheat (which received very great damage from this kind of blight in 1725 – the extent of which had never been heard of before, and I hope will never be heard of again).

Other blight is prevented and cured through hoeing to increase nutrients to the plant

The second kind of blight (of light ears) is more usual and causes great scarcity of wheat. The cause of this is blight is usually a want of nourishment to perfect the grain, but this second kind of blight may also be from the plant's death or injury.

[239] Again, it is remarkable how sophisticated Tull's understanding of botany and other science was, considering the limited equipment he was working with. Seeds are, in fact, impregnated by pollen. –A.B. & M.C.

Blight from lightning and other extreme weather; discussion on lightning rods

Into this second kind of blight may be grouped lightning and other extreme weather, which has been known to occasionally kill or injure plants (the effect of lightning may be observed by the black spots and patches in fields of wheat during years that have more lightning than usual).[240]

Against malnourishment, much can be done. Against death or injury, little can be done. Against lightning there is no defense[241]: the ancients will tell you that the Titans found that even the mountains were not thunder proof. And yet, Columella says:

[240] Though lightning is not such a great problem in North America as it is in Europe, we face similar challenges from tornadoes, floods, earthquakes, and countless other disasters that would destroy not only the plants upon the field but the field itself! To protect against some of these disasters is an easy thing, but against others there is little defense: lightning can be diverted from the crops by a lightning rod and floods can be prepared for by a process of ecological reserve that keeps drainage areas vegetated; yet, though we have heard that Pecos Bill could lasso a tornado away from his family's lands, no one else seems to have learned this technique for us to share. Earthquakes (which can cut a ditch right through a field) are equally difficult to prepare for. —A.B. & M.C.

[241] Lightning rods affixed to the tallest parts of the field and farm structures (barn, house, etc.) will prevent this blight. Lightning rods are a structure composed of a metal rod (which must necessarily be taller than all other structures or trees in the vicinity) that has a sharp knife-like point on the top (the electricity of the lightning is attracted to the point because it is the object closest to the clouds, and the shape of the knife-like top helps direct the lightning into the metal pole to which it is attracted). Attached to the metal pole near to the knife-like point are metal wires that are anchored to the ground. These wires channel the lightning to the anchors, which usually are nothing much more than metal rods that are driven several (or several dozen) feet into the ground. A lightning rod does not prevent lightning, but it does control where the lightning strikes and will protect crops, people, animals and structures from being burned by the electricity: the lightning seeks the easiest connection from ground to cloud, and the rod facilitates this connection better than stalks of wheat, chimneys, windmills, roofs, etc.

The lightning rod was invented by Benjamin Franklin for the public's good (the great man never sought monetary gain from his inventions, and never patented any of them to better facilitate their diffusion to the public). His invention had roots in experiments with electricity that taught Franklin that electricity is conducted easier by some materials than others. To prove his theory, he invented the first lightning rod and demonstrated it on a very thunderous evening: he attached to a kite string a metal key and to this key he attached a metal wire that was attached to a metal anchor. He then flew a kite in the storm. When lightning struck the kite, it did not flow down the kite string to kill Franklin, but traveled down the metal wire to the ground. Centuries later, physics would discover the reason why electricity was better conducted by some materials than others after understanding the atomic structure of those materials: some materials (such as metals) more readily share and convey electrons. –A.B. & M.C.

"Diverse experience of things itself, and labor, has shown new means of welfare to the wretched; and practice, as a teacher, has taught the farmers to still the raging winds and to avert the storm by Tuscan rites. Hence, so that evil Blight[242] *does not dry up the green plants, She is pacified by the blood and entrails of an unweaned puppy."*[243]
Columella, Lib. X

What credit can be given to the fine words of these ancients who join all together in verse and prose to impose upon posterity in matters of fact? By the most elegant expressions, they compose a theory of agriculture without reason and truth. They were most accomplished masters of the art of cheating themselves (and us) with sound instead of sense.

Lodging of wheat, or stem failure, comes from malnourishment and too-great crop density resulting in too little air, water or sun

It often happens that when tillage, dung, and good land have brought a crop of wheat in April or May to promise a yield to the farmer of 40 or 48 bushels per acre, in June the crop falls down and then barely yields 5 or 6 bushels per acre (making it more expensive to reap and thresh than the crop is worth).

Though many farmers understand that lodging results in the ruin of a crop, few farmers understand what results in lodging. Without understanding the causes, it is not likely that the farmer can remedy the disease.

One cause of blight is the lodging or falling of corn, when the stalks are broken or bent near the ground. This results in the vessels of the stem to be pressed so that the sap cannot pass through them, preventing the free circulation of sap to the fruit and to the plant at large. The compression of the vessels also results in blocking the circulation of that which the roots ingest to the leaves: the nutrients cannot be brought to the leaves to be turned into sap. If it doesn't kill the plant, lodging will prevent the plant from producing enough sugar to fill the fruit.

The weakness of the stalks that occasions their falling proceeds from a want of nourishment, air and sun or heat, in combination or individually.[244] Who doubts that nourishment effects the

[242] Personified as the Roman goddess 'Rubigo' —Justin Walker

[243] *"Utque Jovis magni prohiberet fulmina Jarchon / Saepe suas sedes percinxit vitibus albis... / Ipsa novas artes varia experientia rerum / Et Labor ostendit miseris ususque magister / Tradidit agricolis ventos sedare sarentes / Et tempestatem thuscis advertere sacris / Hinc mala rubigo virideis ne torreat herbas / Sanguine lactentis catuli placatur et extis"* Translation by Justin Walker.

[244] This is correct and is a reminder that disease in any organism has its roots in malnutrition and poor hygiene: with adequate nutrition, the defense systems of an organism function better and the creature is strong enough to achieve its full potential; with adequate hygiene, the tax on the organism's defense systems is lessened. Hygiene and adequate nutrition is the best defense against disease in all organisms and planting crops in rows with wide aisles that facilitate the elimination of waste gas and stagnant water from the field (hygiene) and tilling in the aisles (nutrition) are the surest defense against blight. For aquatic plants, good hygiene is obtained still by wide aisles or increased flow of water – the waste gas of the plants is more easily taken away by the water then. Even aquatic plants require the intake and expulsion of gasses (though the gasses are dissolved in the water)–A.B. & M.C.

yield of a field? I have seen that an acre twice as rich as another can yield 40 bushels easier than an acre half as rich can yield 24 bushels.

Air and nourishment are important to curing and preventing blight, but nourishment is more important than air

Air is less important than nourishment: air is necessary to the life and health of all plants – though in different degrees. Aquatic plants are content with as little air as their companions the fish. But wheat, being a terrestrial plant, requires free and open air (albeit, wheat can live many days under water in the winter – though when under water, it does not increase or flourish). Wheat does not succeed in low sheltered places so well as upon higher and opener situations where air has greater motion and can more easily carry off the recrements from the leaves and shake off the dews and rains that would suffocate them by remaining in the vesicula of their leaves.

These dews, shaken off the leaves, find a more proper place at the base of the plants, where the moisture nourishes the roots. A lack of motion from the wind will weaken the plants (as a lack of motion in animals will leave them sickly and unable to stand). Weakened as they are from lack of motion, the wheat will be more easily pressed down by the weight of the rain and more unable to rise up again when down.[245]

Sunlight and heat are also important to keep the wheat strong and in good health. In Egypt and other hot countries, wheat does not lodge so much as in northern countries.[246]

Every leaf has a structure like a kind of knot that delivers out the sap to be purified at the vesicula of the leaves, and receives it back again for the nourishment of the plant. In this way, this knot performs the office of a heart: the sun with his rays supplies the pulse to keep the sap in motion and carry on its office of circulation (instead of our heart's systole and diastole). Wheat, being doubtless originally a native of a hot country[247], requires by its constitution a considerable degree of sunlight and heat to bring it to perfection. If much of that sunlight or heat is wanting, the wheat will be weaker. When the solar rays cannot reach the lower parts of the stalks, the lowest knots cannot do their office – for which reason the water the roots take up must climb higher in the plant if they are to be turned into sap. By the sun's influence, the stalks will harden like bone to support the plant; without the sun, the stalk remains more like cartilage, soft and weak, unable to sustain the weight of the ear. The weakened stalk feebly yields and lets the ear fall to the ground where it will be blighted.

Late blossom is another cause of blight

There is another cause of blight: wheat coming too late into blossom.

The time between generation, blossoming and maturity of the grain is – or ought to be – two months. The usual time of blossoming is the beginning of June. If it is later than June, the days

[245] This is also the effect of fertilizers, which cause the plant to grow too quickly and none too strongly: they will not recover when pressed down by weather or animals. –A.B. & M.C.

[246] Sunlight does has a strengthening effect on the wheat, encouraging the plant to make its stalks strong. –A.B. & M.C.

[247] In fact, wheat originated in Mesopotamia. –A.B. & M.C.

shorten so fast after the solstice that the autumn will be hastening the winter of wheat's life during what should be its time of summer of pregnancy. When it flowers too late, the wheat fails to fruit or becomes abortive, not fully growing its grain.

On this the ancients say:

for just as women have a certain number of days until birth, so too do trees and plants.[248]
—Varro, Lib. I, Cap. 44

In the month of May they bloom, thus corn and barley and those plants which are of a single seed shall bloom on the eighth day, and then, with the flower shed, they grow for forty days up to the condition of ripeness.[249]
—Palladius

The grain is in the sheath for 15 days, it blooms for 15 days, it dries out for 15 days, and then is ripe[250]
—Varro, Lib. I, Cap. 32

But what the ancients did not understand is that the different heat that there is in different climates may alter both the time that plants continue in blossom, and the time between the blossoming and ripening.

Therefore it is not only advantageous to hasten the time of blossoming and protract the time of ripening, but possible to effect that desirable hastening and protraction.

I have observed that the earliest sown wheat generally escapes this blight the best because it comes into blossom early enough. But it seems it was quite otherwise in the climate that Virgil describes which, I suppose, must be where the winters are so mild that if wheat were sown early it might chance to blossom before the hazard of the nipping winds and last frost were past (which happens in Italy to be during March so piercing as to be able to destroy the tender wheat blossoms).

The winters are so mild at Messina that, without much art or skill, they may produce green peas, cauliflowers, artichokes and other fruits and vegetables as good as we have here in the summer. Therefore wheat cannot be kept back from blossoming as it can be here by the frost and if their wheat harvest in Sicily is about the 20th of May (as I have been informed it is), its time of blossoming must be at the beginning of March.

Human error causes blight, too: Virgilian agriculture is one such error

Of all the errors in the first *Georgic* of Virgil (which I believe contains little else but errors), Virgil's remedy against the blight seem the most ridiculous:

[248] "*Ut enim mulieres habent ad partum dies certos, sic arbores ac fruges.*" Translation by Justin Walker

[249] "*Mense maio, florent sic; frumenta et ordeum et quae sunt seminis singularis octo diebus florebunt et deinde per dies 40 grandescunt flore deposito, usque ad maturiatis eventum.*" Translation by Justin Walker

[250] "*Quindecim diebus esse in vaginis, quindecim florere, quindecim exarescere, cum sit maturum frumentum.*" Translation by Justin Walker.

Qui, ne gravidis procumbat culmus aristis
Luxuriem segetum tenera depascit in herba
Cum primum sulcos aquant sata

And left the stem too feeble for the freight
Should scarce sustain the head's unwieldy weight
Sends in his feeding flocks betimes t' invade
The rising bulk of the luxuriant blade
E'er yet th' aspiring offspring of the grain
O'ertops the ridges of the furrow'd plain[251]

All the injury that ears receive by falling is that it makes them light. Lodged ears are always lighter than those of the same bigness that remain standing. Therefore Virgil, instead of "gravidis" should have said "levibus" if he had due regard to strict truth (which might have been some service to his subject he wrote of). But, Virgil plainly mistook the cause of its falling, namely "stalks weak at bottom." He stumbles in the fallen wheat while his eyes are intently fixed upon the sky; he tries to both learn the rules of steering the plow, and to find a vacancy wherein to place the conqueror of his own country among the stars.[252] Virgil's advice prevents the blight by doing what the blight would do, making the cure as bad as the disease.

Heavy ears never fall, and if they did, that would not make them light. Wheat falls sometimes while it is still in grass and before it comes to ear! Virgil's remedy is a false one: we find that those who practice the method of feeding their wheat to sheep in the spring to prevent the lodging of it have the weakest straw and lightest ears.

Virgilians, instead of making the stalks strong enough to support the heavy ears, make the ears light enough to be supported by weak stalks. They know that heavy ears make the greatest crop, and yet still hope to have great crops from light ones. Virgilians cause blight by the very means they hope to cure it.

This feeding of wheat to sheep in the spring very much retards the time of its blossoming, and blossoming early is one of the surest defenses against the blight; by retarding the growth of the wheat, they welcome the blight. And, much worse, when wheat is fed to sheep, the plants require

[251] Tull cites this translation from Dryden, though the present editors could find no other information on Dryden or his work to complete the citation as we completed other citations in this book. –A.B. & M.C.

[252] Virgil shamed his country by using his poetry to provide divine excuse for the Imperial Dictatorship with the false argument that despotism is somehow as natural a solution to humanity's ills as grazing sheep on wheat is an agrarian solution to the wheat's ills. Do not be confounded by Virgil's lies: wheat does not need sheep to protect it from producing more fruit than it can hold, and people do not require enslavement to protect them from holding more power than they can wield or otherwise save them from themselves! We have heard here in America recently the same argument from those who would corrupt a moderate government into the crudest of despotisms. Rome was punished with the loss of Her freedom by the gods she ceased to obey to serve as a lesson to others that might commit the same folly. The gods command their worship through service to the land and people of the nations that they protect: undertake service to your government and your neighbor with the same zeal as your farming and you will prosper. –A.B. & M.C.

longer to stand than the first would have required, and is consequently weaker because the longer time it must grow, the more nourishment is required to maintain it and the soil – which must now go longer after being tilled – can provide to this wheat less nourishment. With less food and more need for nourishment, the crop is in danger of the starving blight as well as endangered by blossoming late!

Virgil's remedy is worse than the disease and I am sure that whenever sheep break into my drilled wheat in the spring, it lessens my crop in half wherever they eat the wheat.[253]

The horse hoeing husbandry removes all the causes of blight (except extraordinary ones, like lightning)

The most effectual remedy against lodging blight is that which removes all its causes (except extraordinary ones, such as lightning). This effectual remedy is, of course, my horse hoeing husbandry!

Curing want of nourishment: hoeing aisles feeds plants

The horse hoe will, in the wide aisles, give wheat throughout all the stages of its life as much nourishment as the hoer pleases.

Curing want of air: aisles conduct air through crops; do not align rows with sun as all plants will with the proper density receive adequate light: align rows with the prevailing winds to either increase air or decrease air

Air, being a fluid, moves most freely in a straight line. A straight line offers the least resistance to its parts: a straight river runs swifter than a crooked one (at equal declivity) because less of the water strikes against the banks at turnings. The banks slow the river.

The air cannot pass through broadcasted wheat in a direct line because it must strike against and go around every plant (they stand all the way in its course and stop the current near the earth). The air in the broadcasted corn (like water amid the reeds on the banks of a river) is stopped in its course so that it becomes an eddy. And, since air is more than 800 times lighter than water, we may suppose its current is more easily retarded – especially near the earth where the wheat has the occasion for the most air to pass (for though the upper part of the wheat is not able to stop a flow of current of air, it can hinder it from reaching the stalks. Thus the air around the stalks in broadcasted wheat remains stagnant). The thicker the wheat is – where it stands promiscuously – the less the air circulates. The greater the number of stalks, the more air they require.

But the confused manner in which the plants of broadcasted what stand is such that they must all oppose the free entrance of air amongst them (from whatever point of the compass they

[253] Indeed! Who looks upon the cattle or sheep that escape into their fields as welcome guests, counting themselves fortunate that the animals chose their field to graze upon? Why do we not pay the grazier to use the wheat fields in the winter, but require payment before the animals see the field? Good fences may make good neighbors, but more importantly, allow better yields by protecting against errant livestock! –A.B. & M.C.

come). Now, it is quite otherwise with wheat that is drilled regularly with wide aisles[254]. Through the aisles the wind can pass as freely as water in a straight river where there is no resistance and communicate its fertilizer[255] to the lower (as well as) upper leaves. The air can carry off the wastes the plants emit and will not suffer the plants to be weakened (as animals are when their lungs are forced to take back their own expirations and debarred from a sufficient supply of fresh untainted air). The benefit of fresh air is plentifully and pretty equally distributed to every row in a field of hoed wheat with wide aisles.

Curing want of sun

It is true that the whole field of plants will receive the same quantity of light, whether the plants on it stand irregularly or regularly. However broadcasted wheat, by their irregular position, may be said to stand in one another's light. For the lack of light, they will lodge.

In drilled wheat, where the plants stand in a regular order, the sunlight is more equally distributed to all parts of the plants in all parts of the field. Whichever way the rows are directed (if they are straight), the sunlight must fall sometime of the day in the aisles and be reflected by the ground to the lower parts of the wheat. The stalks, which receive the greater share of the heat (being nearest to the point of incidence and having no weeds to shadow them) thus grow strong.[256]

Curing late blossom: the horse hoeing husbandry allows farmers to plant earlier

As to that cause of blight caused by the wheat dying before the full time of its pregnancy can be accomplished, the hoe allows the farmer to plant earlier, allowing the wheat to blossom earlier and stay green weeks longer than unhoed wheat planted adjacent to it on the same day.

Curing Moar Loore blight (subsiding ground blight): throw more soil onto the beds from the aisles

Another sort of lodging blight is called by some "moar loore." Moar loore usually happens on light land, when the soil sinks away from the roots to leave the bottom of the stalk higher than the subsided ground. Thus the plant has only these naked roots to support it (for which they are too weak) and falls down to the earth.

[254] Some farmers will align their rows with the sun, but a minor application of geometrical mathematics will demonstrate that no matter how the rows are aligned, the plants will receive an equivalent amount of sunlight. Here, Tull argues for aligning rows according to the need for wind. In dryer climates, the rows should be aligned to shield against the drying air, in moister climates the rows should be aligned to dry the wet crops. The sophisticated farmer will even go so far as to account for where the winds will come from during critical periods of plant growth, and plant windblocks or wind channels. –A.B. & M.C.

[255] Tull's word was "niter" and both the ancient use of the word and the modern understanding of the effect of air on plants agree: the air contains many nutrients –A.B. & M.C.

[256] In hot, dry climates, this is not always an advantage. However, if tall plants or weeds are allowed to grow in the beds, and if trees are planted nearby to reduce the ambient temperature, the damage from too much heat will be avoided. –A.B. & M.C.

To remedy this, turn a shallow furrow against the rows when they are strong enough to bear it and when the soil is fine and dry. Then the motion of the stalks by the wind will cause the soil to run through the rows and settle about the roots to cover them.

Blight can be avoided entirely in most years, and in years of universal blight, damage can be reduced enough to still allow profit: against the universal blight, the horse hoeing husbandry does as well as the common method in a normal year, and the common method fails utterly.

I have never seen any wheat drilled in my new method so much spoiled by falling as broadcasted wheat sometimes is. The drilled never grows so densely that the air cannot enter to the hollows that are near it, and the wind keeps the ears in motion.

Notwithstanding all the precaution that can be used, in some unseasonable years wheat will inevitably be blighted (I have known such a general blight when some of my lammas wheat, planted late and on blighting land, was blighted with the rest of my neighbors by the insects). But the grain of the neighbors was vastly more injured than mine: theirs was so light that it was not fit to make bread while mine made as good bread and had as much flour in it as any of theirs in a blight-free year: the grains of mine were twice as large than those of theirs. In a year of general blight, mine did as well as theirs in a year without blight.

Columella argues that tillage should not be limited, as the more frequently it is undertaken, the more benefit is gained; the ancient Romans could not discover how to hoe their grains, and Tull's invention of the aisle allows this tillage

The ancients were nearly perfect masters of viticulture. Viticulture occupied their rural studies so much as to prevent them from so much as a reflection on how to apply their learning that allowed them to increase their wine to increase their bread.

One method they discovered to be most beneficial for the increasing of the wine was to hoe the vines after they blossomed to help the plants fill their fruit.[257]

[257] Columella repeatedly recommends hoeing of grain crops as well. Yet Columella complains that he cannot hoe the grains all season long because the plow and harrow would destroy the crops! It is Jethro Tull's remarkable invention of aisles and beds that allows tillage all season long.

"*As to vineyards which have become worthless through long neglect, it is agreed by all that the worst course of action is to directly replant them because the lower soil is imprisoned by a tangle of many root – as if caught in a net – and has not yet lost that infection and rottenness of old age by which the soil is poisoned, deadened and numbed. For this reason a piece of wild land is an especially better choice for the vines, even if occupied by bushes or trees (which are easily cleared) because all things that have naturally sprung up do not push their roots far nor to a great depth, but spread and extend them through the surface soil. And when they are cut off with the axe and rooted out, the little bit that remains in the lower soil may be dug up with mattocks and brought together, heaped and composted. But if you have no wild ground, the next choice is to plow the land that is free of trees. And, failing this, remember the orchards or an olive grove...last of all, as I have said, is the renewing of the worn-out vineyard: if circumstances make this necessary, all remaining parts of the vines should be first rooted out, then all the ground should be fertilized with dry manure or compost (or, if this is unavailable, with the freshest manure of another sort) and then turned over: all the unearthed*

"Then it is right to fill it out by frequent diggings, for it becomes more fruitful by breaking up the soil."[258]
Columella (Lib. 4, Cap. 28)

And what Palladius says (Tit. ix.) of the serrations and sarculations of the month of January is true (that if the beans undergo that scratching operation twice, they will produce so much fruit as to fill a bushel almost as full shelled as unshelled!).

If the bean-plant is twice-hoed, they will be successful and yield much produce, even so much that, having been ground up, it will nearly match the measure of a full modius[259]*, just as if it were unground.*[260]; [261]

This is to be done when the beans are 4 inches high and when corn has 4-5 leaves per plant...but even then the harrowing work (though it tore up some of the plants) was observed to do some good against the blight.

if you have hoed dried fields, most of all you have provided something against blight, if the dry barley will be hoed.[262]

When the ancients observed this it is a wonder that they did not plant their wheat to be capable of receiving this benefit. They might have imagined that what was effectual against the blight when the wheat was in grass must, in all probability, be much more effectual when in the ear.

roots must be carefully brought to the surface and burned, and then dig again the ground and cover it with either old manure (because it does not produce weeds) or with soil bought from the bramble thickets." (Columella, Book III, Ch. II, 2-5). *"Vines are set for the most part either in planting-holes or in furrows. Those whose habit it is to set the vine in planting holes excavate the soil in a hole 3 feet wide and 2 feet deep to the width of their spade...leaving a space according to each man's habit of tilling...if the soil is merely to be turned by a spade, the minimum distance between rows is 5 feet and 7 is the maximum. But if with oxen and plow, the minimum is 7 feet, while 10 feet is large enough."* (Columella, Book III, Ch. 13, 1-4). *"no limit should be set to the number of times that the ground is to be turned by hoes, since it is agreed that the more frequent it is, the more beneficial is the digging"* (Columella, Book IV, Ch. 5, 5)--A.B. & M.C.

[258] *"Convenit tum crebris fessiombus implere, nam sit uberior pulverationibus."* Translation by Justin Walker.

[259] A Roman corn-measure, almost two gallons – Justin Walker. 2 Gallons is equivalent to a 1/4 bushel –A.B. & M.C.

[260] *"Taba* [this typo was corrected to "Faba" – A.B. & M.C.] *si bis Sarculetur proficiet, et multum fructum et maxium affcrit, ut ad mensuram modii complendi fresa propemodum sicut integra respondeat."* – Translation by Justin Walker.

[261] Tull did not even cite which author this quote is from. After exhausting searches, we could find no author to ascribe it to but believe it to be a rough translation from Columella, book IV.

[262] *Si sccas segetes farculaveris, aliquid contra Rubiginem praestitisti, maxime si ordeum siccum sarrietur.* – Translation by Justin Walker.

Insect blight

But the most general blight that happens to wheat in cold climates is caused by insects, which (some think) are brought in the air by an east wind accompanied with moisture a little before the grain is filling with that milky juice that later hardens into flour. These insects deposit their eggs within the outer skin (or rind) of the stalks and when the young ones are hatched, they feed on the Parenchyma and eat off many of the vessels which should convey this juice. Because of this, the grain is more or less thin in proportion to the number of vessels eaten and as the insects come earlier or later. Sometimes the insects come too late and the grain is sufficiently filled with the milky juice before the vessels are eaten – then, though the straw may appear through a microscope to have its vessels very much eaten and torn and be full of black spots (the excrement's of these insects), the grain is plump and not blighted.

I observe that the early sown wheat generally escapes this blight and have seen, where one part of a field is sown earlier than the other part, without any other difference than the time of sowing, that the grain of the latest sown has been much blighted and the grain of the earlier has escaped the blight (though the straw of both were equally eaten by the insects). Hence I infer that the milk in the one had received all the nourishment necessary to its consistence before the vessels were destroyed, but in the other, because of the vessels – which should have continued the supply of nourishment for thickening the milk – being spoiled before they finished that office, caused the grain to be thin. Yet the grain of both are equally plump until they become hard, the difference therefore is only in the thickness of the milk (the blighted being more watery than the other).

The chief argument to prove that these insects are brought by an east wind is that the wheat on the east sides of the hedges are more blighted – even when the west side is sometimes unhurt. Some would use evidence that some fields are more likely to suffer this blight and others are more immune to argue that the insects breed in the soil and crawl up the stalks. But it is likely that those fields which are more subject to this blight have an eastward situation, and those that are not have a westward situation.[263]

Whither these insects go or where they reside from the time of their eating their way out of the straw until their return the next year I cannot learn.

Another cause why some wheat is more blighted than other wheat on the same land is the different condition in which the insects find the wheat. The rind of the wheat that is strong and flourishing is soft and tender (into this they can easily lay their eggs), but the wheat that is poor and yellow has a hard skin into which the insects are unable to bore for their eggs. Thus, the grasses with hard skins suffer no mischief.

[263] Tull is quite right to use logical deduction to identify the causes of insect blight. Further inquiry would have brought Tull to achieve what would not otherwise have been discovered for hundreds of years and allow him the credit of not only the father of modern agriculture, but the father of ecological science as well. Some insects migrate from their place of birth, others are born and die on the same ground. To prevent insect blight it is not so necessary to know from where the insects come, but to provide every obstacle to their campaign against your crops: begin a New Deep Hoeing Husbandry, let the weeds grow among the beds in reservations and you will find that, after the ecology recovers from the damage you had been causing it (recovery usually does not take more than a single year), you will suffer almost no more loss from predation. –A.B. & M.C.

It is ill thought to prevent this blight by making your crop poor and hard-skinned. Though the poverty of the crops will starve them and make them resistant to this blight (as poverty protects people from gout[264]), this is a remedy that few would willingly take against either disease.

But, this I think might be possible to remedy if we could, from the strongest wheat, take away so much nourishment as to turn its color a little yellow just before the insects come (which is usually June), after the ear is out and fully formed. Yet this can only be done in wide intervals, for unless the fine soil can be thrust some considerable distance from the roots after the roots are cut off, the roots will regrow and reach it, becoming more vigorous from the tillage.

In dry summers, this insect misfortune seldom happens: much heat and little moisture are most agreeable to the constitution of wheat. In warm, dry years, the wheat's rind is hard and firm, and in wet, cool years, it is soft and spongy.

The most easy and sure remedy that I have yet found against the injury of insects is to plant a kind of wheat that is least likely to be hurt by them. I suggest the white cone (or bearded) wheat, which has its stalk (or straw) like a rush (not hollow, but full of pith – except the lower part, where it is very thick and strong). It is probable that its sap vessels lie deeper because, when the straw has the black spots (which show that the insects have been there to breed), the grain is still plump even when the gray cone and lammas wheat mixed in with it are blighted.

This difference might have been from the different times of ripening (white cone being ripe about a week earlier than grey cone wheat and later than lammas wheat), but having planted white cone wheat early and late and always seeing it escape unhurt by the insects is an argument that it is naturally fortified against the injury of these insects. In wet summers, these insects are so pernicious to other sorts of wheat that I can impute it no other cause of than the deepness of the vessels – the straw of the other kinds of wheat being very much thinner and hollow from top to bottom, and the white cone having a small hollow at bottom (and even there the thickness between the outer skin and the cavity is more than double that of other varieties of wheat). I imagine that because of the thicker skin of the white cone wheat, the insects reach only the outermost vessels and enough of the inner vessels remain untouched to supply the grain.

If the miller does not grind it too finely or the baker does not make his dough too hard, this white cone wheat makes very good bread. White cone wheat is softer than other flour, and a bushel of this white cone wheat will make more bread than a bushel of lammas of the same goodness (but it gives a little yellow color to the bread).

[264] Gout is an arthritic disease caused by eating animal protein: animal protein was a luxury food in Tull's time and the poor could not afford it. Today, though the poor can afford animal protein, it is still the most expensive food source on the market in terms of cost per calorie, cost per nutritional value or other assessments...and still causes gout. Animal protein should be avoided by all those who require their body to be healthy and strong. The wise farmer will proscribe it from their farm, both for their own health and the health of their workers, their animals and their family. –A.B. & M.C.

CHAPTER THIRTEEN: OF SMUTTINESS

Smuttiness is when the grains of wheat, instead of being filled with flour, are full of a black, stinking powder. I don't know that smuttiness is usual anywhere but in the cold northern countries: if it was common in Greece or Italy, they would have a word to express it by in their languages.

Smut is caused by moist soil not from precipitation or condensation upon the wheat

I believe smuttiness to be caused by cold, wet summers and I was confirmed in this by several plants of wheat that I had taken up when they were young grasses in the spring and placed in troughs at my bedroom window. I had placed some of their roots in water (as I had done with the mints). These wheat plants sent up several ears each but, at harvest, every grain was smutty and I observed that none of the ears ever sent out any blossom. This smuttiness could not be from any moisture that descended upon it, but had to have come from the soil (which was always kept very moist). The wheat plants in the field from which they were taken brought forth very few smutty grains and brought much larger ears than these.

Smut also caused by the contamination of the seed-wheat and may be cured by brining (or pickling) and obtaining new seed stock after smut strikes

Whatever the cause is of smuttiness, there are there various remedies, most commonly brining (or pickling) the wheat and changing seed (the importation of new seed after not using the seed from the field to replant the next year).

Brining (or pickling) was discovered in 1660 on accident when a ship carrying wheat sank near Bristol in autumn and farmers obtained the seeds and planted them. Only the brined remained unsmutty that year; an experiment by two farmers whose lands lay intermixed demonstrate that brined seed does not get smutty when unbrined seed does

Brining (or pickling) wheat to cure or prevent smuttiness was accidentally discovered about 70 years ago (about 1660) when a ship load of wheat was sunk near Bristol in Autumn. Afterwards, at Ebbs, the cargo was recovered after it had soaked in sea water. But, though the grain was unsuitable for making bread, a farmer sowed some of it on a field and found it grew very well. After it was learned that the seed would grow, farmers bought up the seed at a very low price and planted it throughout England. At the following harvest, all the wheat in England happened to be smutty except the produce of the brined seed! This accident was sufficient to justify the practice of brining ever since.

I knew two farmers who farms lay intermixed. They bought the same seed together and parted every load between them in the field. The eldest believed brining to be but a fancy and sowed

his seed unbrined. The other brined all his seed. When the eldest farmer had crops that were very smutty, the younger did not.

What to brine seeds with: pure salt, not urine (which is poisonous to the seeds)

Wheat for drilling must have no other brine than that which is made of pure salt, for if there is brine of meat among it, the grease will not suffer the wheat to be dry enough to be drilled.

If seed wheat is soaked in urine, it will not grow. Even if the seed is only sprinkled with urine, most of the seed will die unless it is planted immediately.

Lay wheat seeds in a pile and then sprinkle or lave strong brine water onto it. Turn the pile with a shovel and brine it again. By quick repetitions, the wheat is made equally wet. Repeat the process with powdered quick lime, coating each seed with it until the seeds are dry.

The most expeditious way of brining wheat for the drill is to make very strong brine and, when the wheat is laid in a pile, sprinkle or lave the brine onto it. Then, turn the pile with a shovel and then lave on more brine. Turn it again with a shovel until by many quick repetitions of this, the wheat is all equally wet. Then sift on quick lime through a sieve, turn the wheat with a shovel and sift on more lime. Repeat this many times, until the wheat is dry enough to be drilled immediately. This has been found sufficient to preserve the uninfected wheat from smut in a bad year.

To dry the wheat, we use quick lime which has been beaten to a powder and sifted. This confines the brine to the surface of the grains and suffers none of it to be exhaled by the air. But when the lime has grown weak it is unfit for this purpose.

Brine does not cure smutty wheat unless the year is very favorable

Smutty seed wheat, though brined, will produce a smutty crop unless the year is very favorable: favorable years will cure the smut as quickly as unkind ones will cause it.

Before the brine process had been discovered, farmers imported wheat from foreign countries when all of the English seed was smutty: this change of seed is still useful

Before brining was used and the bad years had caused all the wheat in England to be smutty, farmers resorted to bringing their seed from foreign countries to get clean wheat. It is certain that kind years cure the smut, but to prevent the injury of a bad year, plant clean seed that is well pickled. Yet, to choose between the two remedies against smuttiness, proper change of seed is the most certain.[263]

A very worthy gentleman assures me that since he found a place from which to buy seed to plant his land, these last 10 years he has not had a smutty ear in any of his crops (and he never brines

[263] For this reason, we undertake the expense of buying fresh, clean, inspected and certified seed from seed growers every year. –A.B. & M.C.

or limes his seed) even when all the other wheat in his neighborhood has been smutty. He says the person that sells him his seed also changes his seed every year.

It is possible to suspect that the sunken wheat at Bristol was foreign and thus not smutty, but the experiment of the two intermixed farmers proves the effectiveness of the brine

This gives me a suspicion that the drowned wheat at Bristol might possibly have been foreign and that it would not have been smutty the next year even had it not been soaked in sea water...yet the wheat sown by the two brothers demonstrates that the brine and lime cures the infection.

While the soil and growing conditions of the seed wheat may affect the growth of its subsequent crop, it is most important that the seed is clean

There is the old rhyme that sand is a change for no land, and the belief that seed from strong clay land is best for seed wheat, that seed from red clay is best for planting in white clay, that seed from white clay is best for planting in white. But from whatever land the seed is taken, if it had not been changed the preceding year, it might possibly be infected and there is the danger even if came from a proper soil.

The strongest objection to annual crops of wheat is the danger of smuttiness. However, with good tillage, the soil moisture is controlled and smut does not occur

The strongest objection that has yet been made against constant annual crops of wheat is that those grains of the precedent crop that happen to shed before or during the harvest grow in among the following crop and endanger the entire field with the risk of smuttiness. All I can say in answer is that for the past 5 years that I have had a constant crop of wheat, this inconvenience has never happened to me (even when the precedent crop has been smutty). The reason for this I believe to be that a crop which has been very early planted is not apt to be smutty, and if the seed is not planted early (such as the grains that are shed), the seeds will grow only to be killed by at or before the time of the next crop's planting. This saves the crop following a smutty one and when the former crop is planted with good seed, the shattered grains of the precedent crop will produce clean wheat the following year.

And it is very unlikely that any breed of these grains should remain to grow a crop in the third year.

Jethro Tull's Supplement

Equivocus's errors

Although by a natural sympathy he has with falsehood, Equivocus may have an attachment to ancient errors, his defense of what is wrong in these Roman authors may yet be possibly owing to his ignorance, except that he perverts what is right (if anything besides a fine style be right) in them.

He is so ignorant of the difference there is between the climate of England and that of Italy, as in p. 143. of his Essay for June, to direct from Columella the sowing of winter vetches for feeding green on the ground by cattle in the winter, which has not heat enough to bring them to a substance for feeding of the fifth part of the value of the seed sown, nor of the twentieth part, were we to sow so much on an acre, as he directs (six bushels). The climate of Naples is indeed so warm, that such forage will grow to be a large crop in winter.

Equivocus seems to be also partly led into this shameful blunder by his ignorance in the etymology of the name, in which he pretends to be so well learned. They are called winter vetches, because they are just able to endure the cold without dying, and when winter is over, they grow and become a crop. But Equivocus thinks they have their name on account of being a crop in the winter.

He is as ignorant too in the difference of English and Italian measures of land and corn, which makes him direct the sowing three or four times more seed than is necessary and usual to sow and it is certain that they sow less seed of vetches and winter corn in Columella's country than here, because there none is killed by the cold.

Equivocus says, in p. 136 of his Essay for May, that "as the situation and soil of those countries are very different from that of Great Britain, few of their rules will be here mentioned." But how he contradicts himself in this particular, see his preface to September, not paged, where to show the world what an ignorant pretender he is, he most ridiculously reproaches all our English modern authors for not recommending to our countrymen those rules and precepts of ancient Romans, which every man of reason, acquainted with the world, must know are impossible to be practiced in our climate.

He prefers the knowledge of the ancients in their choice of soils and their manner of working and plowing them.

From the first he takes the great discovery that strong land is better for corn than light hollow land and gives this reason for it: "for whatever the husbandmen of any age may think, corn does not do so well on grounds, which are naturally hollow light, as they do on those which are made so by plowing: because in one, the earth naturally closes in again round about the roots, and keeps the moisture from being exhaled too fast: whereas ground which is hollow or light, detains it not at all." Those are the poorest of all the reasons that can be given to prove the strong land is better than light, for it is from the misfortune of subsiding too soon, and retaining moisture too long, that our strongest lands in wet years fail of their crops, when our light lands produce good ones.

Strong land (clayey or silty) has more food for plants than light land (sandy)

A cubic inch of strong land, being heavier, is better in quantity, and has more earth in it than a cubic inch of light land, as a loaf without leaven has more bread in it than a leavened loaf of equal dimensions; for it is the weight that determines the true quantity of a soil and of bread.

Also strong land has generally a deeper staple, whereby it exceeds light land in dimensions too; a superficial foot of twelve inches' depth having twice as many cubic inches in it, as a superficial foot of but six inches depth.

And it may be a question, whether this advantage of quantity both in weight and dimensions is not greater than the advantage strong land has over the British light land, on account of their different qualities. If you take a pound of strong and a pound of light earth, and reduce them to a very fine (and almost impalpable) powder, I believe, you will find that each will just fill a box of equal dimensions; but how long each, being exposed in the field, will continue in this artificial state

of equal specific gravity cannot be exactly known from any observations as yet made, though doubtless it will be the longer, by how much the more frequently they are stirred or agitated.

So much for the difference in quantity of these two sorts of soils, but the different qualities by which each has the advantage over the other are too many for me to enumerate at present, any further than I have done in my Essay; wherein may be seen how false that assertion of Equivocus is, "their (the moderns') thoughts have reached no deeper than the surface of the earth, and though many sorts of timber, nay, Lucerne, and a great many other grass seeds, require soils almost as deep as an oak tree does, there has not been one word said of it by any of them." See my Chapters of Lucerne, sanfoin, etc., which show this to be a false calumny.

Deeper soil provides more food for plants

And I verily believe there is not one farmer in England that rents an acre of land without inquiring or examining into the depth of the staple of it; the bottom of it is one of the first views his thoughts reach to, being aware that the depth of the soil is one of the principal things whereon the success of his labor depends. If that depth of soil were not necessary our farmers must throw away their plows for there would be no need for plowing: says he, "his (Columella's) words are to the following memorable effect, viz. *Nec contentos case nos oportet, prima specie summi soli, sed diligenter exploranda est inferioris materiae qualitas, terrene necne sit? Frumentis autem sat erit, si aequa bona suberit bipedana humus, arboribus altitude quatuor pedum abunde est.*"

Which translates thus: "In the choice of soils we ought not to be contented with the upper face or surface of it, but should diligently seek the qualities of the inferior materials or strata below, to see if it be a living earth or good soil underneath (for so we understand the word Terena to signify); soil of a foot thick, if it be equally good, will do for corn, but for the trees it ought to be four feet."

There is no doubt but that by the words *terrene humus*, Columella here means what we call the staple or upper stratum of earth, wherein the plow is or may be properly exercised; but for this learned lawyer to translate *bipedana humus*, soil of a foot thick, instead of two feet thick, intimates a design of imposing upon his "lower class of readers, who are not able to distinguish," etc., and who would despise any author that should give them instructions to choose a soil that is scarce possible to be found, and harder to be had. For a soil or staple of half a foot or eight inches deep would not be despised by any practical farmer.

Yet the farmer whose lands are confiscated, forfeited or legislated can provide no food to their plants no matter how good the soil

Yet choice of soil, indeed, seems to be of little immediate concern in Britain where confiscations and forfeitures are less rare than they were in Italy in Columella's time, so that our lands are taken away from the ancient owners to be distributed to such men of merit and industry as the Equivocal Society seems to hope they will.[266]

[266] Indeed it seems that the only plausible explanation for Equivocus's bad advice, if ignorance and stupidity are discounted, is an interest in buying farmland cheap. We laugh as we try to pardon

Land is brought into tillage by plowing

However that may be as it is, let us, while we have them, see the ancient "manner of working and plowing them, in all which (Equivocus says) Columella has left direction not to be excelled, and from a quotation of two lines only from Virgil also, has said more on the subject of tillage than all the moderns have who wrote since; it is there, that speaking of putrid, cold, watery land, those two authors direct the plowing of it as the only method of bringing it into tillage." A great discovery, indeed, that land is brought into tillage by plowing!

Equivocus's poor Latin translation

But what a perverter is Equivocus when he asserts that Virgil means putrid, cold, watery land, by *Nigra fere et pinguis terra, cui putre solum optima frumentis* (which is evidently a blackish, fat, mellow land, and the best of soils, as putrid, cold, watery land is the very worst)! For the society says, in page 15 of Preface to August, that the too great quantity of water standing too near the surface is as great a cause of barrenness as the entire want of it: but yet a soil that is naturally mellow, differs much from a soil which is made so by plowing; and the most mellow soil that is, will produce but little corn without plowing.

Equivocus, to show further his utmost ignorance in the subject he pretends to write of, gives the world the following false translating of part of Columella's 4th Chapter, Lib. XI;

Medium igitur temperamentum maxime sequamur in arandis agris; ut neque succo careant, nec abundant uligine.

Which he renders thus in English: "That we chiefly have regard to a medium or temperature of weather in the plowing of our fields, even so as that they may not want proper moisture for the nourishment, nor abound so much with it as to spoil the corn." He perverts the sense of Columella by foisting in the spoiling of corn, by the too much or too little moisture, when the degree of moisture relates only to the effect it has on the pulverization of that land; for he must be very ignorant to think that the same degree of moisture in which the fields are plowed, will continue in them till the corn has occasion of it, since there is always an absolute necessity of vicissitudes of weather, after this first plowing before the fields can be made fit to be sown with corn.

The next thing, on account of which he extols the ancients and reproaches the moderns, is the sorts of wheat the ancient sages were possessed of, that are not sufficiently regarded by the moderns, the Bimestre and Trimestre, "so called from their ripening in two or three months after they were sown." And one of them (from Pliny) was ripe in forty days after it was sown; but after the advantages he proposes from our sowing them, and all his quotations and etymologies of them, though the one be called *Triticum aestivum et Trimestre Portae*, and the other *Triticum aestivum et Zeopyrum tritico speltum*, this virtuoso doth not pretend he ever saw either of them, and allows that he does not know whether they are wheat or barley. And yet reproaches our modern authors for having "said so little of it, that it is difficult in general to understand what they sow those grains for; though some few practical farms in Stafford and Oxfordshire, &c., may." If they are sown by the practical farmers

the senseless advice of those savants more modern than Equivocus who are equally bad for land values! –A.B. & M.C.

so near London, it is a wonder this practical farmer should be no better informed concerning those wonderful, hasty, and advantageous grains.

The reason and truth of these ancient worthies appear pretty equally in their erroneous poetical religion, astronomy and agriculture. Any one of them may be defended as well as the other, for that dead men are gods or stars, that the sun sets in the sea, and that pulverization is poison to light soil are equal absurdities, and he who writes for restoring such errors of the ancients, though his language in verse or in prose should be as fine as theirs, can be but sound instead of sense.

Light and hollow soils are improved through tillage

I am inclined to believe that a thorough tillage might be a remedy to such a loose hollow soil; for it is certain, to a demonstration, that it would render it more dense and increase its specific gravity; but to enrich it sufficiently without manure the tillage must pulverize it much more minutely and expose it longer than is required for the strongest land. Sheep also would be very helpful on such hollow land; but the long strawy dung that Equivocus prescribes to it would make it more hollow.

Wheat drilled and hoed does not lodge

I have never seen any drilled wheat so much spoiled by falling as sown wheat sometimes is. The drilled never falls so close to the ground, but that the air enters into hollows that are under it, and the wind keeps the ears in motion. Notwithstanding all the precaution that can be used, in some unseasonable years wheat will be blighted: I have known such a general blight, when some of my Lammas-wheat, planted late, and on blighting land, was blighted with the rest of my neighbors by the insects; but the grain of the sowed wheat was vastly more injured than that of the drilled: the former was so light that the greatest part was blown away in winnowing and the remainder so bad that it was not fit to make bread. Yet the drilled made as good bread, and had as much flour in it, as the sowed wheat had that was not blighted: the grains of the drilled were much larger than those of the sown, being formed to have been twice as big as the grains of wheat generally are, had they not been blighted.

Of all the errors in the first Georgic (which I think contains little else) Virgil's remedy against the blight seems the most ridiculous

Qui, ne gravidis procumbat culmus aristis
Luxuriem segetum tenera depascit in herba
Cum primum sulcos aequant sata

And lest the stem too feeble for the freight,
Should scarce sustain the head's unwieldy weight,
Sends in his feeding flocks betimes t'invade
The rising bulk of the luxuriant blade;
Ere yet th' aspiring offspring of the grain
O'ertops the ridges of the furrow'd plain.
—Dryden

This indeed prevents the blight, by doing what the blight would do if the wheat fell down, i.e., causes the ears to be light.

A theoretical origin of plowing better than that proposed by Equivocus: humans observed the effect upon plants and seeds by wildlife digging and turning soil, not divine education; theological arguments from Genesis against Equivocus's heathen beliefs

And had Equivocus resided in the country, he might have seen hogs (as mad work as he thinks they would make in a field) till some sorts of land better than the Virgilian rastering in Hampshire and Wilts, which sometimes does not quite half-plow the ground. And certainly a hog is a better tiller than an ass is a pruner. Why then it is not as likely that heathen tillage should be discovered from a hog as pruning from an ass?

If tillage were inspired at first by the Author of all things in any other manner than by making man a rational creature, than it is certain that the Mosaic tillage, if we knew what that was, would appear to be different from the Virgilian, which is very imperfect. But whatever is the work of miraculous inspiration, it is undoubtedly true that when God made man he furnished him with everything necessary for his sustenance. But tillage, such as we mean, was not necessary for that purpose before mankind became numerous, for in some countries people have subsided without it several thousand years since the creation of the world. Therefore, whether the inference Equivocus draws from Genesis be right, I am not a theologist enough to determine, that not being my profession. Neither would I in anything impugn the meaning of the Holy Writings knowingly.

I am now writing against heathens of whose errors Equivocus is an advocate, and therefore it might be unfair to quote Moses against them or him, if it had not appeared in his *Essay* that he had read Genesis, where in the first and second chapters he might find himself condemned an infidel and atheist.

I leave it to be determined by the reader which of the two is more likely, that a hog should first imitate a man, or a man a hog in digging; since none but such an infidel as Equivocus will deny that hogs were diggers before men, for that would contradict Moses in describing the creation, in which brutes had the priority.

CHAPTER FOURTEEN: OF SANFOIN

Sanfoin is also called French Grass because it originated in France, Everlasting Grass because it can last upwards of 40 years, yet it is not a grass (strictly speaking). It is also called Sain Foin, Sanum Faenum, Sanctum Faenum (Holy Hay) because it is more wholesome than other hay whether dry or green. Sanfoin provides excellent bee pasture, as well.

Sanfoin is also called "French grass" because of the country from which it originates. It is also called "everlasting grass" because its hay can sometimes last more than forty years. Yet it is not (strictly speaking) a grass and so it is called by the French Sain Foin, Sanum Faenum, Sanctum Faenum, or Holy Hay. It gets its name from its quality of wholesomeness that exceeds that of other hay (whether green or dry). [267]

Sanfoin has red flowers, leafing ears 5 to 6 inches long, stalks commonly 2 feet long but under good husbandry more than 5 feet long

It is a plant so generally known to everybody (except a certain author who somehow confuses it with alfalfa) that there is no need to give any formal description of that part of it which appears above the ground. It has many red flowers, sometimes leaving ears five or six inches long. I have measured my stalks and found them more than five feet long – though they are more commonly about two feet long.

Sanfoin has a tap root that allows it to produce hay in poor ground

The reason why sanfoin will in poor ground make a forty times greater increase than the natural turf is because of the prodigious length of its perpendicular tap root. Its taproot will descend more than twenty or thirty feet, commonly exceeding fourteen feet.

Sanfoin's taproot can break through hardpan and will run deep anyway; sanfoin has a multitude of very long horizontal roots at the upper part of the root

There is the vulgar opinion that sanfoin will not succeed on any land where there is not a hardpan to stop the roots from running deep (for fear that the plant will spend themselves in the roots only and the parts above the ground will not thrive). So ill thought is this argument that I am almost ashamed to give an answer to this; it is amazing to hear such reasoning from men.

[267] We enjoy it as it provides excellent hay and good pasture for bees as well. We can allow the flowers to bloom and feed the bees without worrying about poisoning the hay. And, sanfoin flowers make excellent honey. –A.B. & M.C.

It is certain that every plant is nourished from its roots (as an animal is by its gut) and the more and larger roots it has, the more nourishment it receives and prospers. Sanfoin always succeeds where its roots run deep and when it does not succeed, it never lives long enough to have long roots. Neither can there ever be found a sanfoin plant that lives so long as to root deep in soil that is improper for it.

This tap root has also a multitude of very long horizontal roots at the upper part that fill all the upper stratum of the soil – the staple of the ground. Of the thousands of sanfoin roots I have seen taken up, I have never found one that was without horizontal roots at the surface after one summer's growth. I do much wonder at how Mr. Kerkham should be so mistaken as to think that they have no such horizontal roots!

The tap root has horizontal roots all the way down, but as they descend, they are shorter and shorter so that the uppermost are always longest.

Sanfoin prefers dry lands, and can do well on poor lands, but does best in rich dry land

Any dry ground may be made to produce this noble plant, let it be ever so poor. But the richest soil will yield the most of it and the best. If you venture to plant it with the drill according to the method wherein I have always had the best success, let your land be well prepared before you plant it. If not well covered and ordered, very little of your seed will grow. Therefore it is convenient to try it in the manner mentioned in the Chapter of Hoeing where are also directions to find the quantity and depth to plant it at.

Generally, do not plant more than 1/2 inch deep; cover them very well. 1 bushel to an acre (20 seeds per foot) ensures some seeds will succeed – thin them to the proper distance afterwards

I have observed that the heads of these seeds are so large and their necks so weak that if they lie much more than 1/2 an inch deep, they are not able to rise through the incumbent soil. And, if they are not well covered, they will be malted (we say it is malted when the root dies from exposure to the air because it lay above the ground when it sent its root out). A bushel to an acre is full twenty seeds to each square foot, and these odds make some difference to the number of seeds that succeed.

The kernel or seed that is swollen in the ground I call the *head*. This, when it reaches above the ground, opens in the middle and forms the two first or primary leaves. The husk always remains at the depth at which it was planted. The string that passes from the husk to the head is the *neck*, which, when by its too great length is unable to support the head until it reaches to the air, rises up and doubles above it. When it does so, the head – being turned with its top downwards – can never rise any higher and rots in the ground.

In very light land, seed will come up from a greater depth, but the most secure way is not to suffer seed to be covered deep in any land. Whether we plant bad seed that does not grow or good seed that that is buried or malted, the consequence will be the same and the ground will be equally understocked with plants.

Worst season to plant sanfoin is the beginning of winter and in the drought of summer

The worst seasons to plant sanfoin are the beginning of winter and in the drought of summer. The best season is early in the spring.

Sanfoin grows best when in monoculture, the worst plants to grow with the sanfoin are clover and ryegrass; less bad are barley and oats, but are very bad none the less

It is stronger when planted alone and when no other crop is sown with it. The worst crop that can be sown among the sanfoin is clover or rye grass. Barley or oats live only a short time and rob it only a little, but when the other artificial grasses rob it for a year or two until the artificial pasture is nearly lost, the sanfoin will never arrive to half the perfection as it will do when no other grass is sown among it[268]. The injury of these hay crops do to sanfoin is best seen where some parts of the same field have them and the other parts are without.

If the barley, oats or other grains that are sown with sanfoin lodge, it will kill the young sanfoin that is under it. But, then so great a crop of grain will certainly answer the very little expense of drilling the sanfoin again, either the next year or as soon as the corn is off the ground![269]

[268] The farmer who wants to segregate the sanfoin may want to plant alternating beds in sanfoin and grass so that, if customers desire pure sanfoin, they can harvest along the beds, but if customers want a mix they can harvest across the beds. –A.B. & M.C.

[269] Columella says that "*it is no mark of a wise farmer to be more concerned with fodder for his cattle than with food for people, especially when they may obtain the fodder just as well from pastures. I am so strongly in favor of hoeing beans as to think that they should actually be hoed three times, for I find that when cultivated in this way they not only multiply their yield but also have but little pod in proportion and that a measure of them when shelled and cleaned is almost as full as before they were shelled – the amount is scarcely diminished by the removal of the outer coverings. And, in general, as we have said before, winter hoeing is of very great benefit on clear and dry days after the solstice is past in the month of January – if there are no frosts. It should be done, besides, in such a manner that the roots of the plants are not damaged, but rather covered over and hilled up so that the offshoots of the main stem may spread out farther. It will be beneficial to do this at the first hoeing, but harmful at the second because grain roots (if covered after the second hoeing) will rot if covered over after it has ceased to send out shoots. Therefore, nothing more should be done at the second hoeing than to loosen the ground evenly.*" –Book II, Chapter XI, 7-8. We agree with Columella that it is foolish to plant food for animals before food or fuel for people when hay earns so much less. So often, though, for lack of resources, a farmer is forced to act unwise; sometimes they are unable to till their beans once, let alone 3 times! When Sakata Farms (then one of the largest fruit and vegetable farms in Colorado) in Brighton was unable to hire enough hands to harvest their broccoli in 2006, was it unwise for them to leave the broccoli to rot on the field? Would it have been wiser to sell their cabbages as food for their neighbors' cattle? Usually it would be madness to sell broccoli as cattle feed, but there are times when a farmer will grow hay for lack of time, labor or capital to grow better crops, and while "it is no mark of a wise farmer" to grow hay, it is the mark of a wise farmer to make the most of what resources they have and to make hay while the sun shines. This is Tull's chief argument for growing sanfoin and other hays, and we agree wholly with its logic. Yet today, with agricultural subsidies making havoc of the natural price relationships of grain and

When sanfoin is planted among barley in a dry summer, there are few farmers that will know until the next spring whether the sanfoin succeeds or not because the young plants are not visible.

To know if the sanfoin will succeed you must be accustomed to observe them in all the degrees of their growth. I have seen a field of ten acres of such wherein, after the barley was carried off, nothing appeared like sanfoin. But, when by the print of the channels I searched diligently, I found the small sanfoin plants thick enough in the rows. They had no leaves (having been carried off by the scythe) no part of them that was left had any green color. But from the plants there came out many sprigs like hogs bristles or like the beard of barley. This whole piece of sanfoin succeeded so well that the third year its crop was worth three Pounds per acre, the land being good.

The quality of seed impacts the number of seeds planted per acre: bad seed needs more seeds per acre; to know the goodness of the seed, plant a certain number of seeds in soil, observing the rate of germination – or cut a certain number of seeds in half to observe what proportion have a green, fresh color inside (are viable).

The quantity of seed to be drilled on an acre will depend in great measure upon the goodness of it. With bad seed, not more than 10% will grow. With good, fewer than 5% will miss. To know the goodness of the seed, take a certain number of seeds and plant the kernels in the soil in the manner directed by the experiment for finding the proper depth to plant at (in this case, about 1/2 inch). Then the quality of the seed will be known by observing how many seeds germinate. If you cut the kernel in the middle (cross ways) and find the inside a greenish, fresh color, it is surely good seed – but if it is a yellowish color and friable about the navel, and thin or pitted, it is bad seed.

Until frequent experience has furnished enough experience to the planter to know the difference between good and bad seed, let the planter observe that the following are signs of good sanfoin: the husk is a bright color and the kernel is plump and of a light gray or blue color (sometimes a light black)...though sometimes the seed will be good even if the husk is of a dark color – if the dark color is caused by the seed receiving rain on the field and not by heating in a heap or in the mow.

The number of seeds to drill ought to be computed by the number of plants required for the best crop (allowing for casualties), though we need not be very exact in the number of plants (whether they are 200, 300 or even 400 on a perch [a perch is 272.25 feet – 1/160 of an acre]). It is not possible to know beforehand the precise number of plants that may live –sometimes the grub kills many by eating off the first two leaves.

hay, it may, indeed, be the mark of a wise farmer to grow hay instead of grain! The wise farmer obtains the highest use of their land, and while for many farmers this may mean food for their household (such produce earning the freedom of a life of leisure when what inconsiderably little land tax is paid by the homesteader), for other farmers this means earning vast sums of wealth through cash crops. The hazards some farmers undertake with cash crops of extraordinary value (such as narcotics, which demand not only all the agricultural skills, but many martial skills as well if the crop is to be defended against both natural predators and human thieves) demonstrate something of an opposite goal to the food-growing homesteader's objective of leisure. The wise farmer obtains the highest use of their land, and the wisest farmers know what that is for them and their household – A.B. & M.C.

The experiment of Tull's seedmen who (against Tull's direction) broadcasted sanfoin instead of drilling: the drilled sanfoin outperformed the broadcasted

Many, even of the best seeds – both broadcasted and drilled – are liable to casualties, but not equally. About 28 years ago, my servants (being prime seedmen) had a fancy in my absence to try an experiment on the difference between sowing and drilling sanfoin. In the middle of a large field of my best land, they sowed a square piece of three acres at a rate of one bushel to an acre, believing that their skill in broadcasting it evenly would succeed as well as if it were drilled. But it succeeded so much against their expectation that the land all around it – which was drilled at the same time with the same proportion of the same seed – brought extraordinary good crops of sanfoin while the broadcasted part was so very thin that, though it laid still with the rest for 8 years, there never was more than three or four harvests from it. It can be supposed that broadcasted sanfoin will always meet with so many casualties as this did, for even had they planted 8 bushels of seed to the acre it might have been too thin (and much thinner than all the rest of the field was, even though it was only drilled at one bushel to an acre).

Even 3 to 4 plants per square yard is sufficient for a good crop

In drilling sanfoin, my quantity is 1 bushel to an acre, though sometimes I use as little as 6 gallons. Even smaller quantities suffice. One year, a single acre (in the middle of a large field of sanfoin) was drilled late in October and the frosty winter killed at least 95% of all the plants of the bushel I planted. But there remained living 3 or 4 plants to each square yard, and these plants stood single and at pretty equal distances.

The field was so empty at first that it seemed that whatever sanfoin was growing there was growing by accident, or that the field had been plowed up for a summer fallow. But by summer, a few plants (which, by their singleness) grew so vigorous and large that they were very visible, and by the second year of mowing, produced a crop double to the rest of the same field that was drilled in the spring with the same proportion of seed but had none of it killed by the frost. And this remainder planted with 1 bushel to the acre did better than that which was planted in the common manner with 7 bushels to the acre.

Thin fields make the best crops after the first or second year. Plant so that plants appear to be single or isolated: general rule is to plant 5 seeds per square foot, with rows 16 inches apart

I have generally observed that the thin plantings make the best crop after the first or second year. I commend planting sanfoin so thin that most of the roots may be single...but the amount planted seems to have little impact on the density of the roots. I have fields that were drilled with four gallons of seed to an acre with rows 7 inches apart, and yet the roots are so thick in them that the ground is covered with the sanfoin plants. There, they seem to be as thick (in appearance) as most broadcasted sanfoin whereon 7 or 8 bushels are sown on an acre. I prefer my other fields that were drilled with 2 gallons of seed to an acre (which is five seeds to a square foot!) with rows 16 inches apart because they produce even better crops, though the ground is poorer.

More important than planting density is the aisles: natural experiment with the hoeing of sanfoin and resulting lawsuit

More important than planting density is the manner of planting. Drilled sanfoin, being regular, is more single, though as thick as the sown, and for this reason always makes a better crop and lasts longer than the broadcasted that is of the same thickness but irregular.

When sanfoin is planted in the Common Fields (but not those fields that are Common for sheep), horses and oxen will sometimes accidentally scratch and scrape a multitude of sanfoin plants while plowing upon the edges of the fields not planted in sanfoin. I once knew lawsuits to be made with the intent of obtaining recompense for the damage, but after the trial was long over this scratched and scraped part – supposedly spoiled! – became twice as good as the rest of the same field where the plows did not tear up the plants.

The reason why thin sanfoin makes the best crop is that each plant has adequate nourishment

The reason why single sanfoin plants make the greatest crops is that the quantity of the crop is always in proportion to the quantity of the nourishment it receives from the soil, and those plants that run deepest will receive the most nourishment, and those that are single will run deeper than those that are not.

Also the single send out all around them horizontal roots proportionally stronger and larger to their singleness, whereby they are able to better penetrate and extract more nourishment form the staple of the soil than others might do. It is common to see a single sanfoin have a bigger taproot than 20 sanfoin plants seeded thickly together. The length of sanfoin roots is in proportion to their bigness, therefore a single plant may well be supposed to have 20 times more depth of soil to supply it with food than all those 20 small roots can reach to. And, though these deeper layers of soil are not so rich in food as the upper layers, they do still afford considerable quantities of nourishment to those roots that enter them.

The small, thick plants are so far from equaling the production of a single large plant because of the excess of their numbers. The more numerous the plants are, the smaller and shorter and weaker they become, the less nourishment they have and the less crop they produce. They are soon starved, decay and die – unless relieved by the expense of frequent manure or that the soil is very rich.

Single plants exceed the others in as a giant does a dwarf in strength and stature. The single plants also exceed the others in their longevity, for I have seen that when sanfoin has continued good for a great number of years without manure, the owners usually decided to plow it up at the beginning to thin the numbers.

Sanfoin does not have to be replanted if planted properly and does not starve – a lesson from the Japanese art of bonsai

I have never known a plant of sanfoin die a natural death (the most common end of it is starving)[270]. And, when a hundred thick plants have not the nourishment that one single plant has, it is no wonder that these (in a crowd, thus besieged with hunger) should be starved before the single one dies. Broadcasted plants, when too thick, are crowded on every side...but those that are drilled too thick have always room enough on two sides of them (unless the rows are too near together).

Thin plantings have more soil moisture per plant than thick plantings

Another advantage the single plants have, in respect to moisture, is that the single plants can reach to a depth where water is never wanting – even when the upper layers of the soil are parched and dry. As appeared with the Mint G in the glass and box of sand, if any root of a plant has moisture, that root will communicate a share to all the rest. Hence it is that in the driest summer, these single plants make a great crop when the others yield next to nothing.[271]

3 tons per acre yield can be easily expected, second cuttings possible

I remember I once saw a farmer coming out of his fields with a load of sanfoin hay, which he assured me was all he could find worth cutting out of 40 acres. He had planted it thickly 3 years ago, and his entire harvest weighed 3 pounds. Needless to say, those 3 pounds came off so much ground that the expense of mowing, raking, etc. was more than the value of the hay. In the very same dry

[270] Far away in Asia, the Japanese had already learned this lesson and developed the art of bonsai.

The Japanese learned that by trimming the roots and the buds of the tree, the tree could be made to live forever young. Perverting the learning towards the heinous torture of the trees they subjected it to, they proved that – despite the horrific mutilations designed to make the tree look old (such as ripping its bark, bending it sideways, forcing it to extreme dwarfism and even exposing its roots to the air) – by the proper treatment of the roots and buds, the tree could withstand not only these trials but also age itself. The tree became a metaphor to teach, but the Japanese bonsai artists proved poor students, taking from the bonsai spiritual lessons and leaving behind all those that were agricultural. Why the Japanese did not apply their learning to their agriculture is a question we could not discover an answer to. –A.B. & M.C.

[271] Many deep rooted plants will pull moisture up from the depths of the earth and, in feeding themselves, will deposit some of that water in the soil. In an experiment, we have raised a good crop of lettuce under alfalfa bushes with no irrigation because the alfalfa not only shaded the lettuce from the parching sun, but also supplied the lettuce with enough water. This was repeated with various deep-rooted weeds with similar effect. A living mulch of bindweed (morning glory) was also experimented with success – so long as the bindweed was kept off the plants it improved soil moisture content. The use of purslane as a mulch was more effective, but dubiously so: in harvesting the purslane for sale, the mulch was removed! –A.B. & M.C.

summer, there were 3 tons of sanfoin to an acre in my fields, where it was drilled thinly and regularly.

And I have often seen that, where the plants are thin, the second crop springs immediately after cutting – even when plants that stand thick in the same ground do not begin to regrow until the rain comes. And I have seen the thin grown high enough to cut a second time before the thick began to regrow!

The proper planting density is found by considering the size of the adult plants

The best way to determine the proper planting density is to consider what quantity of hay one large plant will produce[272]. With proper hoeing, all plants will be large, without hoeing these plants never attain to a fourth part of the bulk they do with it. Therefore, very few people have seen even one plant at its full bigness. One plant well hoed has in the same ground made a greater produce than one thousand small ones unhoed.

A large plant will produce more than 1/2 pound, at least 1/4 pound. With 17,920 plants per acre, if each weighs 1/4 pound, 4,480 pounds per acre will be harvested; if each weighs 1/2 pound, 8,960 pounds per acre will be harvested.

The hay of a large, single, hoed plant will weigh more than a half pound – and with 17,920 plants upon an acre, weighing but a quarter pound apiece one with another, amounts to 4,480[273] pounds per acre.

If planted in spring, sanfoin may yield a crop the same summer, but typically the next year

If sanfoin is planted on some kinds of soil early in the spring and hoed, it may bring a crop the same summer. I once planted a few seeds of it on sandy ground in my garden at the end of February, and they produced large plants above two feet high that went into blossom the following June – even though there was severe frost in March that killed much of the wheat, the frost did not hurt these plants! Sanfoin is a quick grower, unless it is planted on poor cold ground (or for want of food).

And though the poor land and ill management generally allotted to sanfoin allows it to yield only one mowing per year, it has yielded two great ones on rich sandy land when planted on poor land and well managed.

[272] This is true for all crops. Consider the adult size of the plant and space each plant within the row at this width. To determine the minimum space required between rows (remembering that more space is better), it is a good general rule to double the intrarow spacing so that another plant could fit in the space. –A.B. & M.C.

[273] Jethro Tull had rounded down to 2 tons in the original text (4400 lbs)

Just as an orchard of apples will not cover all the ground at first, a sanfoin field thinly planted will not cover all the ground at first. Apples are planted 30 feet apart in presumption of their final size: plant sanfoin far apart so it can grow to obtain its full potential

Thin sanfoin cannot be expected to cover all the ground at first, no more than an orchard of apples will when first planted at 30 feet distance from each other in every way. Yet this is reckoned a proper distance to make a good and lasting orchard, and if the trees were to be planted at the 3 foot distance they stood at in the nursery, it would be no more unreasonable than the common method of planting sanfoin is: there would be much of the same consequence in both if all the ground was covered at the first planting – except that the sanfoin, being longer rooted downwards than apple trees are, has the greater disadvantage when, by its thickness, it is prevented from growing to its full bulk.

The difference between a field of sanfoin and an orchard of apples is only this: people are accustomed to see apple trees planted at their due distances, but few have seen sanfoin planted and cultivated at the distance most proper to sanfoin (or ever considered about it so much as to make the necessary trials).

Overstocking a cattle pasture and overstocking a plant pasture result in the same malnourishment; doubling the number of rows (with equal numbers of plants in each row) results in a diminishment of the harvest; leaving out every other row (or halving the number of rows) results in an increase to the harvest

Horizontal rooted plants suffer no greater injury by their pasture's being overstocked than cattle do because their pasture, lying near the surface of the ground, lays all around them. But sanfoin and other long taprooted plants suffer more because the great part of their overstocked pasture is lost by them all when they hinder one another from reaching down to it (by shortening one another's roots), which they do when they all become dwarfs by reason of their over-thickness.

I have constantly found that, upon doubling any number of narrow rows, having equal numbers of plants in each row, that the crops have been very much diminished. Upon leaving out every other row (that is, lessening the number of rows by half) the crops are increased. And, where two rows are wide asunder at one end of a bed and narrow at the other, the plants are gradually smaller and smaller as they approach nearer to each other.

Expect full harvest second year and thereafter by expecting small first crop

We ought never to expect a full crop of sanfoin the first year if we intend to have good crops afterward. After that first year, it will continue to produce full crops forever.

Do not grudge the thinness of a crop: it will produce more pounds of hay

The most common error comes from mistaking the cause of a great or small crop. Where the spaces between rows are wide (if there are not too many plants in them) we always see the sanfoin grow large and make the greatest crop. But when it is young (or after cutting) we see room (as we fancy) for more of such plants to make a yet larger crop.

Where spaces between rows are narrower and the rows of equal thickness, we see the plants smaller when full grown, and that they make less of a crop. And yet, there seems to be room for more rows, which we fancy might make the crop larger – not considering that it is the narrowness of those spaces that cause the plants and crop to be less, for want of sufficient pasture.

Thus, gradually increasing the numbers of our rows and plants, we bring our crop (unless the soil is exceedingly rich) to nothing by too much overstocking of their pasture. And if that pasture is overstocked, the crop will be diminished more than in proportion to that overcharge, for perhaps it is not impossible to prove (if we were curious) that plants, by wanting a 1/4 part of their due nourishment, will be diminished to 1/2 of their bulk they would have attained to had they been supplied with the other 1/4 part: when plants have not their due nourishment, they suffer more from the cold and drought so that the want of nourishment diminishes their growth by 1/4, and the cold or drought (or both, together) diminishes he growth another 1/4 part.

I have observed hoed sanfoin to grow more and increase its bulk more in 2 weeks than unhoed sanfoin in the same ground (and without any other difference) did in 6 weeks. The quicker it grows by being better fed, the sweeter and richer food it will make for cattle – whether it is fed green or dry. Cattle are the best judges off the goodness of hay, and they always choose to feed on sanfoin that is most vigorous and refuse to eat that which is poor and yellow. And the richest, sweetest grass will always make the best hay – the drying of it does not change the quality of the grass.

At whatever distance the rows are set, if they have too many plants in them, the crop will be very much injured. And the greater the excess is beyond the right number, the more void space there will be among them (because the smaller the plants are, the less ground they will cover).

Recommended widths of aisles, beds and rows: double rows in the bed 8 inches apart with aisles 36 inches wide. Though more hoeing is better, it is possible to hoe aisles alternately every year or every 3rd or 4th year if the land is good.

I have had the experience of drilling at all distances, from 33 inches to 7 inches between rows, and recommend the following distances for sanfoin, whether intended for hoeing or not.

First, for the sanfoin intended for hoeing, I think it is best to drill double rows with 8 inches between them and 36 inch wide aisles (which need only be hoed alternately, leaving every other aisle for making hay upon). It is not necessary to hoe sanfoin every year, or even every 3rd or 4th year if the land is good. While the plants are small the first year, care must be taken to not cover them with the plow. Afterwards, there will be no great danger – but the soil should not be suffered to lie on them too long, especially in the winter.

Though I have never yet had an entire field solely in sanfoin, I have had enough land in sanfoin to show me that horse hoeing makes it strong upon very poor land and causes it to produce two crops per year on moderately good land.

If sanfoin is to be hand hoed, rows should be 16 inches apart with 8 inches between each plant in the row

If the sanfoin will be hand hoed, drill the rows 16 inches apart and single out the plants so as to make them 8 inches apart at the least within the rows. Contrive to leave the master plants more than to be exact in the distance. This thinning must be done while the plants are very young (or in summer) or else they will come again when they are cut by the hoe.

If no hoeing is intended, plant single rows 8 inches apart with plants 16 inches apart within the row

If the sanfoin is drilled without any intention of hoeing, the best way (I think) is to plant single rows at 8 inches distance, with no greater quantity of seed than when the rows are at 16 inches distance. By this method, the same number of plants will be in the rows (which are still 8 inches apart) but those plants will be more single.

A well pulverized seed bed is necessary for planting, other planting instructions

Whichever of these methods is practiced, the land should be made as clean from all grass and well pulverized as possible before drilling.

The tines of the drill-harrow must exactly follow the shares (which, leaving the channels open, the tines cover the seed, some at bottom, some on each side) so that the seed is covered very shallowly deep within the ground where there is more moisture than nearer to the upper levels of the surface. This causes the seed to come up in dry weather and yet it is not in danger of being buried by a too great weight of soil on top of it.

Do not plant too deep by harrowing afterward; do not roll the freshly planted seeds

But be careful that no other harrows come on it after it is drilled, for they might bury the seed too deep. I never care to roll it at all (except on account of the barley) and then only in very dry weather with a light roller, length-ways of the rows immediately after it is drilled (or else 3 weeks afterwards, for fear of breaking off the heads of the young sanfoin).

A roller must not be used when the soil under it is moist enough to be squeezed by its weight, it is should be light, bearing only upon the tops of ridges, and of sufficient weight for breaking small clods.

Do not graze upon the sanfoin the first winter after the corn is cut that grows among its rows

Be sure to suffer no cattle to come onto the young sanfoin for the first winter after the corn is cut that grows among its rows – their very feet would injure it by treading the ground hard, and their mouths by cropping it. Nor let any sheep onto it, even in the following summer and winter. The first winter is the time (for unhoed sanfoin) to lay on manure after the crop of corn is taken off because there is no natural grass to partake of it and the plants being less, less manure suffices to supply them. And, because when made strong in their youth, they will come to greater perfection...but I never use any manure at all on my horse hoed sanfoin.

Drilled sanfoin is produces twice as much or more than broadcasted sanfoin, at 20 times less cost

One acre of well drilled sanfoin, considering the different goodness of the crops and the duration of them, is generally worth two acres of broadcasted sanfoin on the same land – though the cost of drilling be 20 times less than the cost of broadcasting.

One of the causes why sanfoin that is properly drilled lasts longer without manure than broadcasted is that properly drilling neither overstocks nor understocks the pasture and broadcasting commonly (if not always) does one or the other or both (plants too thick in some places and too thin in others). When they are broadcasted, it is almost impossible to the plants come up true and regular (or even nearly so). Plants too thick soon exhaust their pasture, and when too thin, the sanfoin cannot be said to last at all because it fails from the start by never once providing a harvest. I have now a great many single sanfoin plants in my fields that are 30 years old and yet seem as young and vigorous as ever. It is common for thick sanfoin to wear out in 9 or 10 years (in poor land much sooner) if not manured by soot, potash or coalash.

Sanfoin in its wild condition in the Calabrian Hills near Croto is planted too dense

They who sow 8 or 10 bushels of good seed on an acre in a good season among their corn (with the intention that by its thickness it should kill the other grasses) reduce their sanfoin to almost that poor condition I have seen in the Calabrian Hills near Croto, where it grows wild without sowing or tillage. It makes there such a despicable appearance that one would wonder how anybody should have taken it into their head to propagate so unpromising a plant. And yet there has scarce been an exotic brought to England in this or the last Age capable of making a greater or more general improvement were it duly cultivated.

Cytisus, alfalfa, assa faetida are not good alternatives to sanfoin

Some think that the Cythifus[274] would exceed sanfoin, but I am afraid the labor of shearing those shrubs by the hands of English servants would cost too much of its profit. Alfalfa, requiring

[274] Also known as Cytisus, is a Genera in the tribe Genisteae of the subfamily Faboideae of the legume family Fabaceae. The Genera Cytisus has about 30-35 member species. All the Genera of the tribe share similar characteristics of dense, slender green stems and very small leaves (which are adaptations to dry growing conditions). Most of the species have yellow flowers, but a few have white, orange, red, pink or purple flowers. They are natives of Europe, north Africa and southwest Asia, with the greatest diversity in the Mediterranean region. Most (but not all) are fire-climax species, adapted to regular fires which kill the above-ground parts of the plants, but create conditions for regrowth from the roots and also for germination of stored seeds in the soil.

The most common species is the common broom (Cytisus scoparius, syn. Sarothamnus scoparius), a native of northwestern Europe, where it is found in sunny sites, usually on dry, sandy soils. Like most brooms, it has apparently leafless stems that in spring and summer are covered in profuse golden-yellow flowers. In late summer, its peapod-like seed capsules burst open, often with an audible pop, spreading seed from the parent plant. It makes a shrub about 3 to 10 feet tall, sometimes 12 feet tall. It is also the hardiest broom, tolerating temperatures down to about -15°F. It provides a useful yellow dye and was grown commercially for this purpose in parts of Britain into the early 19th century. Woolen cloth, mordanted with alum, was dyed yellow with dyer's greenweed, then dipped into a vat of blue dye (woad or, later, indigo) to produce the once-famous "Kendal Green" (largely superseded by the brighter 'Saxon Green' in the 1770s). Kendal green is a local common name for the plant.

more culture and being more difficult to be fitted with a proper soil, can never be as general as sanfoin in England[275].

Mr. Laurence, in his new system of *Agriculture* (page 400) is in hopes of succeeding in his project of cultivating assa faetida[276] in England in lieu of sanfoin, and that it may be a greater improvement than sanfoin or clover. But I must beg leave to suspect a little his sincerity when he delivers his opinion that sheep fatted with silpium or assa would make mutton of such a wonderful pleasant taste as to be preferable and more delicate than that of bagshot-heath – especially when he relates that 1 drachm of it fresh from the roots casts a stronger smell than 100 pounds of it sold by our druggists...and how the whole air of a place is infected with its great stench, and that Ronodaeus thinks that the Indian palates are made of brass to endure it!

Upon the whole, this reverend gentleman's meaning (for all good men mean well) seems to be for introducing as an improvement of another kind than that of sanfoin. If he could prevail with the English to plant Assa all over the Island as frequent as sanfoin and clover, the English noses might become as brazen as those of Ronodaeus's Indians (for those of the London Goldfinders are a million times too nice!). Then, Mr. Laurence's project would be an extraordinary improvement and save the government's immense expense of a Navy to defend us – for though we had no other guard but this general stench of assa, it would be as dangerous for any European to approach England as for serpents and toads to invade Ireland!

When this contrivance succeeds, Mr. Laurence will deserve no less of his country than St. Patrick did of his.

However, because it may probably be a long time before this contrivance is so fully effected as to bring sanfoin quite out of fashion, let us consider in the interim the best methods of planting sanfoin for hay and for seed.

The largest species of broom is Mount Etna broom (Genista aetnensis), which can make a small tree up to 30 m tall. There are many species (such as dyer's broom Genista tinctoria) which are low sub-shrubs, barely woody at all.

Brooms tolerate (and often thrive best in) poor soils and growing conditions. In cultivation they need little care, though they need good drainage and perform poorly on wet soils. They are widely used as ornamental landscape plants and also for wasteland reclamation and sand dune stabilizing. On the Canary Islands, a native species is widely grown as sheep fodder. –A.B. & M.C.

[273] Alfalfa has become general in England and throughout the world, though it has the disadvantages of causing bloat and being hard to grow in most places (both wet and dry, both hot and cold). More acres are currently planted in alfalfa than ever were planted in sanfoin. Yet alfalfa has this advantage over sanfoin: it is more easily grazed upon. Farmers, still unaware that grazing animals upon a field reduces yield, continue to plant alfalfa because it can be grazed upon. Alfalfa is more costly to grow than sanfoin. –A.B. & M.C.

[276] A member of the parsley family, it is now known as assa foetida, and is known commonly as Asafetida, Devil's Dung or Satan's Root. It does, indeed, have a fetid, evil smell. Trials we made in an urban test plot were cut short by our neighbors having a violent intolerance to the smell and threats of police action: the situation was resolved when our good-meaning and friendly landlord returned from a holiday vacation and, upon smelling the nasty stuff, destroyed the plants, believing them to be rotten. –A.B. & M.C.

Sanfoin may be grown for seed, hay and bee pasture, and the farmer need not rely on good weather for haying

The profit of sanfoin fields arise from either of these ways, and it is a great advantage to their owner that sanfoin provides more profit than that of grass hay – when grass hay cannot have good weather to be cut in its season, it can serve for little other use than as manure (but even then the expense of manure and carrying it off cannot be omitted). But if there is not weather to cut sanfoin before blossoming, we can harvest it in flower or wait until the blossoms are off, and if the rain still comes, it may even stand for seed and turn as good a profit as had it been cut before the flower or in flower. Sanfoin has four chances to be harvested to the one of the grass![277]

Hay is made with less expense and with better quality on hills and mountainous terrain because of the reduced quantity and duration of dew

The elevated but not but not mountainous situation of the dry land whereon sanfoin is mostly planted renders it so commodious for making hay that it escapes the injury of the weather when sanfoin hay in low meadows is utterly spoiled. On the high ground the wind will dry more sanfoin in an hour than on the low meadows in a whole day. The sun, too, has a more benign influence above and sends the dew off about two hours earlier in the morning, holding it up as much longer in the evening. By these advantages the sanfoin has more time to dry and is made with half the expense of meadow hay.

The several proper times for cutting sanfoin hay: virgin, blossomed, full grown and thrashed

But before the manner of making it is described, the proper time of cutting ought to be determined.

There are several sorts of sanfoin hay that may be distinguished by the following terms: Virgin, Blossomed, Full Grown and Thrashed.

Virgin sanfoin hay is of the highest quality because no energy has been expended on flowers or seed; an example from potatoes: potato flowers are pruned to increase potato yields

Virgin is the best of all beyond comparison and (except alfalfa) has not in the world an equal. Virgin sanfoin is that which is cut before the blossoms appear. When it blossoms, the most nourishing parts of its juices are spent on making the next generation of sanfoin and the sap is impoverished. The sanfoin will never recover that richness that it had in its virgin state. And, though when it is blossoms it is literally in the flower of its age, it is really in the declension of it. It

[277] Since the time of Jethro Tull, bees have been domesticated to allow the hay farmer even greater yields than the several cuttings allowed by sanfoin or alfalfa. Bees can be grazed on the pasture of sanfoin or alfalfa to yield a valuable harvest of honey. But sanfoin has this advantage over alfalfa: the alfalfa, for it to be serviceable as hay, must be cut before it is in full bloom. Sanfoin can be allowed to bloom fully (to feed the bees) and then can be cut as hay! —A.B. & M.C.

is sometimes said that what is not in stalk has gone to flower, but this is a mistake: much of the nutrition of virgin sanfoin has perspired into the atmosphere.

And, moreover, all vegetables are in some degree weakened by the action of continuing their kind. Some plants live for many years if not suffered to blossom – but when they do blossom, it causes their death (though even in the first year of their life). In plants (as Dr. Willis observes in animals), nature desires to continue the species more than benefit the individual.[278]

Preservation of hay with smoke in damp weather

Part of the drilled sanfoin ground was cut at the beginning of May before blossoming. To cut before blossoming does not mean before any one blossom appears (for here and there a bud will begin to open with a red color long before the rest), but when only a few blossoms begin to open. From that time of cutting until it was set up in ricks (about 10 days) the sun never shown upon it. But the weather was so misty that at last I was forced to carry the hay (still so green that the largest stalks still secreted milky juice) together for fear of rain. Yet by making the hay up into several little ricks and drawing up a great chaff basket in the middle of each for firing, I had the very best hay that I ever had.[279]

[278] Indeed, some farmers will destroy the flowers on their potatoes to force them to invest their energies into their tubers rather than into their seed. The sterilized potato attempts to grow bigger so that the following year it will be better able to reproduce. –A.B. & M.C.

[279] To prevent the spoilage of hay, it is necessary to work actively against those microbes that would eat it. This is done by dehydration of the hay, by the sheltering of hay from precipitation, and the treatment of the hay with antimicrobials.

Tull's dangerous technique is one that both dehydrates and treats the hay with antimicrobials. It ought to be practiced before brought into wide use: though it foiled Monceau, the key is to produce a very small smoldering fire; to smoke the hay rather than to fire it. A small wood-chip fire will likely not destroy the rick, either. The use of smoke as a preservative (it is antimicrobial and antioxidant) with hay is different than with meat: unlike meat, the smoke can penetrate nearly throughout the hay because of its large surface area ratio. The drying of the hay with the smoke also reduces microbial action that would spoil it. Smoke preservation can directly create compounds known to have long-term health consequences, namely polycyclic aromatic hydrocarbons, or PAHs, many of which are known or suspected carcinogens. These compounds result from incomplete combustion of the fuel; hotter wood fires make more PAHs; hot-burning mesquite produces twice as much as cooler-burning hickory.

However, this is no real need for concern. Because of the short life expectancy of the animals that are eating the hay, the risk of cancer from smoked hay is minimal: carcinogens strike stronger against longer-lived animals; thus, while many primates eat an omnivorous diet without cancer, heart or other organ disease or other ill effects, humans (which can live sometimes dozens of times longer than their omnivorous relatives) will develop heart or organ disease from an diet that contains meat. It is both the quantity and duration of the exposure to the carcinogen that results in the cancer risk.

To construct a smoke-rick out of bundled or baled hay, the farmer has two methods at their disposal: they can construct a hay igloo (a self-supporting domed structure – this is easier with bales than with bundles) or a hay tipi (a self-supporting conical structure – this is easier with bundles

This hay, so cut before the blossoming has kept a team of working stone horses round the year fat without corn and, when the horses were offered beans and oats mixed with chaff, they refused it for this virgin hay. Sheep fed it thrived fatter than other sheep at the same time fed with peas and oats. This hay was weighed to them and the clear profit amounted to four Pounds per ton. The animals made no waste, though the stalks were of such an extraordinary bigness that they would break off short (being very brittle). This hay grew on rich ground in Oxfordshire.

The other part of the ground was afterwards cut in the prime of its flower and made into hay by the heat of the sun without rain or mist. This came out of the ricks at winter with a much finer color and as fine a smell as the virgin hay – but did not come near it in fatting sheep or keeping horses fat at hard work without any corn as the virgin hay did.

Poor, uncultivated sanfoin produces dismal harvests

This superfine hay cannot well be had of poor, uncultivated sanfoin because that may not be much above a handful high when it is in condition to be cut and would then make a very light crop and would be a great while before it ever sprang up again. But the rich, cultivated sanfoin will have two or three tons to an acre and spring up again immediately for a second crop so that little or no quantity would be lost.

Hoed sanfoin upon a poor chalky hill, cut at the same time with that uncultivated on a rich valley, does in dry weather grow again without delay when the valley attends a month or more for a rain to excite its vegetative motion. This hay the owner (if he is wise) will not sell at any common price, but endeavor to have some of it every year (if possible) for his own use.

Blossomed

The second sort of sanfoin hay is cut in the flower and is much inferior to the Virgin sanfoin, but far exceeds any other kind of hay commonly grown in England. If it is a full crop, it may yield more than 3 tons per acre. This is that sanfoin that is most commonly made and, the larger it is, the more nourishing it is for horses. I have known farmers, after trialing such sanfoin go 3 miles to fetch the largest stalky sanfoin when they could have bought the small, fine leafy sort at home for the same price per ton.

Full Grown

The next and last sort of sanfoin is that which is full grown, that which has the blossom gone or going off. This is also good hay, though it falls short by many degrees of the other two sorts of sanfoin. It makes a greater crop than either of them, though, because it grows to its full bulk and shrinks little in drying. This gives the owner a third chance of having weather to make hay and spins

than with bales), or they may construct a wood frame (such as a barn, but with no walls) on which to stack the bales or bundles.

Please see the chapter comparing the old and new husbandry for a description of other methods of preserving hay–A.B. & M.C.

out the hay season until midsummer. Then, in about 2 or 3 weeks, the hay is finished and the seed is ripe.

Making Sanfoin Hay

But first the manner of making sanfoin hay![280]

[280] Because baled hay is more common today, some explanation will be given on ricks, cocks and sheaves.



(Science Museum/Science & Society Picture Library picture number 10312698): This photograph was probably taken in England between 1900 and 1930.

The hay is cut and bound into sheaves, or arm-sized bundles. These are then laid upright onto each other to form a cock or stook before being reassembled into ricks. The cock or stook provided temporary protection against the weather.

A rick is nothing more than a large cock with a door for ventilation. Some ricks have a ventilation hole at the top, as well. They resemble tipis in most respects.

The cocks are made into ricks by any one of several methods. Either through skill of balancing, the sheaves are stacked into large, 10-20 foot tall cocks, or are balanced against a center

In a day or two after the sanfoin is mowed it will, in good weather, be dry on the upper side. Turn the swarths not singly, but two and two together, for by thus turning them in pairs there is double the space of ground between pair and pair (which then needs only once raking). Whereas if the swarths were turned singly (that is, all in the same way – suppose to the east or west) then all the ground will need to be twice raked.

As soon as both sides of the swarths are dry from rain and dew, make them into little cocks the same day they are turned (if it is convenient to do so) for when they are in cocks, the less part of them will be exposed to the injuries of the night than when in a swarth.

Dew is of a nitrous, penetrating nature and will enter into the pores of those plants it reaches and, during the night, possesses the spaces from where some of the juices are dried out. Thus it intimately mixes with the remaining sap and when the dew is again exhaled, it carries up most of the vegetable spirits along with it. These spirits might have been there fixed had they not been taken away with that subtle vehicle.

If sanfoin is spread very thin upon the ground and remains for a week thus in hot weather, the sun and dew will exhaust all its juices and leave no more virtue in it than is in straw.

Therefore it is best to keep as much of the hay as is possible from being exposed to the dews while it is drying. Form them into large cocks: the bigger the cocks are, the less surface area (in proportion to the quantity contained within) will be exposed to the dew. Sanfoin may be safely made into much larger cocks than other hays of equal dryness because it will not sink down to exclude the air, and does not therefore require being moved and opened frequently. Sanfoin, by the less flexibility of the stalks, will admit more air and will remain longer without fermenting.

Thus being able to endure more days unmoved is an advantage. Though in other countries where people are not prohibited from using the necessary labor on all days for preserving their hay (though the weather is less certain than here in England), here, many thousands of loads of hay are spoiled by for want of being opened because English labor laws prohibit work on Sundays and holidays. Often by the loss one day's work in England, the farmer loses his charges and year's rent. "To make hay while the sun shines" is a proverb against English laws. Yet sanfoin is, in regard of Sundays and holidays, more conformable than grass hays are to English laws because it can endure more days unmoved.

But to return to our hay makers, when the first cocks have stood one night, if nothing hinders the farmer, let them double, treble or quadruple the cocks as the circumstance requires in this manner: spread 2, 3 or more together in a fresh place, and, after an hour or two, turn them and make that number up into one cock. But when the weather is doubtful, let not the cocks be thrown or

pole, or are laid upon a framework. Usually, the sheaves are bound with rope in place or to each other. When it is time to use the hay in the rick, the entire rick is disassembled and fed to the cattle.

Lighting a fire in the inside is made safer if a ventilation hole is retained near the top of the rick, but the smoke will be more effective if the fire is lit and allowed to smolder inside with the door closed. Make sure the fire is a small one, or you'll have a big one when the rick combusts! Again, we urge caution and practice before attempting it.

If you do not wish to use a basket to hold the flame, metal platforms, fire pits or other contrivances may be had to hold the fire.

Building a platform above the ground to allow ventilation under the stacks of hay (whether baled or ricked) will decrease spoilage, as will tarping the hay. However, a barn is the best place to store hay, and when the amount that spoils every year is accounted for, barns pay back their cost very quickly – often within a few years. –A.B. & M.C.

spread, but enlarge them by shaking several of them into one and thus hollowing them to let in the air. Continue increasing their bulk and diminish their number daily until they are sufficiently dry to be carried to the rick.

This is the best way, though it is something longer in the making, because it reduces the dangers of a great quantity of hay is spread at once – a sudden shower will do more harm to one acre on the ground than to twenty acres in the cock!

The very best hay I ever knew in England was of sanfoin made without ever spreading or the sun's shining on it. This way, though it is longer finished, is done with less labor than the other.

While even a mist will turn clover hay black, sanfoin only turns black with difficulty

Rain is not needed to turn clover hay black, even a mist destroy the hay. But sanfoin will not with any weather turn black. Sanfoin only turns black when it is entirely rotten. This is because its leaves are thinner than clover. If sanfoin is laid up when green it will take no damage from the moisture, provided it is set in small round ricks with a large basket drawn up in the middle of each to leave a vent hole there, through which the superfluous moisture of the hay may transpire.

As soon as the heating is over, these ricks ought to be thatched and all the sanfoin ricks that are made when the hay is fully dried in the cocks ought to be thatched immediately after making them. That hay which is laid up most dried will come out of the rick a green color; that which is much heated in the rick will have a brown color.

Thrashed

The seed is a fourth chance of the owner to make profit of his sanfoin. But this, if the hoeing husbandry were general, would not be vendible in great quantities for planting because an ordinary crop of an acre produces enough seed to drill hundreds of acres and those hundreds of acres would not require replanting for a very long time.

However, though the seed is not valuable for planting, the seed is valuable for feed grain, and it has been affirmed by those who have made trials of it that 3 bushels of good sanfoin seed given to horses will nourish them as much as 4 bushels of oats. The seeds are so sweet that most sorts of cattle are greedy of it. I never knew so much of it given to hogs as to make them fat bacon, but in an experiment I have known hogs made very good pork with it. These hogs were valued at the beginning of their feeding and the pork was valued when the hogs were killed, and the value of the quantity of seed they ate was nearly equivalent to the same value of the seed sold for sowing (the value of the seed for sowing was 3 Shillings per bushel, and the profit made by giving it to the hogs was 2 Shillings per bushel).

The goodness of the seed and the hay out of which it is thrashed depends very much on the manner in which they are made. Thrashed hay, when not damaged by wet weather, has been found to be more nourishing to horses than course grass hay, and when it is cut small by an engine, it is good cattle feed (much better than chaff of corn).

It requires some experience to know the most proper degree of ripeness at which the seeded sanfoin ought to be cut, for the seed is never all ripe together. Some ears blossom before others: every ear begins blossoming at the lower part of it and continues gradually to ripen upward for many days. Before the flower is gone off the top, the bottom of the ear has almost filled the seeds that

grow there! If we defer cutting until the top seeds are quite ripe, the lower ones (which are the best) will be shed and lost.

The best time to cut is when the greatest part of the seed is well filled, the first to flower are ripe and the last to flower beginning to fill.

The natural color of the kernel (which is the real seed) is gray or blue when ripe, and the husk (which contains the seed) is, when ripe, of a brownish color. Both husk and seed continue perfectly green for some time after full grown, and if you open the husk, the seed will appear exactly like a green pea when gathered to boil, and will like peas be easily split into two parts. Yet sanfoin in this green plight will ripen after cutting. Some, for want of observing this, have suffered their seed to stand so long until it was all ripe and lost in the cutting.

Sanfoin seed should not be cut in the heat of the day while the sun shines, for then much (even of the unripe seed) will be shed in mowing. In hot weather, the mowers should begin their work very early in the morning (or late into the night). When they perceive the seed to shatter, they should leave off and rest until evening.

Even after cutting we observe the same rule as in mowing: with sanfoin, we do not make hay while the sun shines!

Sometimes the sanfoin may, if the seed is pretty ripe, be cocked even immediately after the scythe. If the swarths must be turned, let it be done while they are moist. Do not turn them (as with other hay)! Though it is common that rain occasions the swarths to want turning: if the swarths are not very great, we never turn them at all because the sun will quickly dry them. If you do not make the swarths great, you will never need to turn them.

If the swarths must be turned, you can turn them with the rake's handle or teeth. If turning with the rake's handle, it is best to raise up the ear sides first and then let the stub side rest on the ground in turning. But if it is to be done by the rake's teeth, then let them take hold of the stub side, the ears bearing on the soil in turning over.

If sanfoin is cocked at all, the sooner it is made into cocks, the better because if the swarths are dry, much of the seed will be lost in separating them (the ears being tangled together). When moist, the seed sticks fast to the ear, but when dry, they will drop out with the least touch or shaking. Sometimes when we purpose to thrash in the field, we make no cocks at all and only just separate the swarths in the dew of the morning, dividing them into parts of about two feet in each part. By this means the sanfoin is sooner dried than when thicker, as it might do if made into cocks.

Two methods of thrashing sanfoin: on the field, and in the barn. Carry the sanfoin on sheets to avoid losing seeds. Be certain to cure the seed for preservation. Methods of ripening fruit and other produce off the plant are similar to methods of spoilage for seeds that should be preserved: discussion of ether

There are two ways of thrashing it, one in the field, the other in the barn. The first cannot be done in very fine weather and while the sun shines in the heat of the day. The best way to thresh it in the field is to have a large sheet pegged down to the ground for two men with their flails to thrash on. Two persons carry a small sheet by its corners and lay it down close to a large cock and, with two sticks thrust under the bottom of it, gently turn it over and throw it onto the great sheet of the thrashers. But when the cocks are small, you can carry several at once to be thrown upon the little sheet carefully with forks. It is easy to carry the hay away and lay it into a heap or have a child stand upon the hay to make it into a small rick of about a load. As often as the great sheet is full, riddle it

through a large sieve to separate the seed and chaff from the broken stalks and put the seed and chaff into sacks to be carried into the barn to be winnowed.

Two thrashers will be needed to employ two of these little sheets, and four persons in bringing to them more hay to thrash, and one or two persons to cart away the seed and chaff. Seven or eight persons per thrashing sheet are required. The sooner these thrashed cocks are removed and made into bigger ricks the better, and unless they be thatched with the hay itself, if there be not straw convenient for it.

The most important care yet remains, and that is to cure the seed – if that is neglected, the seed will be of little or no value. The better it has escaped the weather in the field, the sooner its own spirits will spoil it in the barn or granary. I have known it to lie a fortnight in swarth until the wet weather has turned the husks quite black. This was thrashed in the field and immediately put into large vessels holding twenty bushels each. It had, by being often wet and often dry, been so exhausted of its fiery spirits[281] that it remained cool in the vessels without ever fermenting in the least until the next spring, and then it grew as well as ever any did that was planted.

But seed thrashed in the field without ever being wetted, if it is immediately winnowed and laid in a heap (even in as small of quantities as a single bushel), or put into a sack, will in a few days

[281] Seeds and fruits and other vegetable matter will emit ethers that ripen and sometimes even rot them. These ethers occur naturally and serve to ripen the unripe fruits (and sometimes occurs artificially when a farmer attempts to artificially speed the ripening of their fruits), but can destroy fruits stored improperly. We have seen a new farmer destroy their entire harvest of fava beans this way. We, ourselves, suffered the loss of all our sunchoke seed when the friendly and good intentioned (but entirely unasked for) help of family moved the seed (against our direction and without our knowledge) to a warm, unventilated room and put all the seed in that room in a large heap while we were out of town purchasing mules and unable to do anything to save the seed: it was all lost.

The more ether surrounding the vegetable matter, the more will be released and so it is important to have a storage area well ventilated if not all of the ether is to be removed prior to storage. Reducing temperature to cool or near-freezing, reducing humidity and maintaining darkness are all tricks used to reduce ethers.

To artificially speed the ripening of fruits (as is usually done with bananas, strawberries, melons, and other crops), either apply the ether gas to the fruits (the ether can be bought as a refined commodity for this very purpose), or store the fruits and seeds you would expose to the ether in a well lit, warm, moist place, in large piles.

Banana farmers construct small dug-out rooms under the trees for this purpose. After sterilizing the soil, lining it with banana leaves (to increase the amount of ether and trap the gas more), and then burying it with soil to make an air-tight atmosphere, the bananas ripen very well; strawberry and tomato farmers will typically have application rooms where unripe fruits are subjected to the gas until sufficiently ripened (tomatoes and strawberries ship best when unripe, and it is customary to ripen them when they arrive at the destination). It should be said, though, that artificially ripening fruits results in an inferior product to those that are ripened on the plant, and reduces the desire of the customer to buy more fruit. The consumer can tell when a fruit has ripened reluctantly and against its will, but will buy these reluctant dainties for lack of other options or resources to afford plant-ripened fruits. Artificially ripening fruits reduces nutrition and flavor.

Seeds are best preserved dry and stored cool. –A.B. & M.C.

ferment to such a degree that the greatest part of it will lose its vegetative quality. The larger the heap the worse, during the fermentation it will be very hot and smell sour.

To prevent this, many other farmers will spread the seeds upon a malt-floor (or when the quantity is small, upon a barn floor) and turn it often. But still I find that by this way a great deal of it is spoiled, for it will heat and ferment even if spread as thin as a handful thick (and they never spread it thinner). Besides, they may miss some of the right times of turning it, for it must be done very often. It should be stirred in the night and the day until the heating is over. And yet, do what they can, it will never keep its color so bright as that which is well housed, well dried and thrashed in the winter.

I thrash, dry and house my sanfoin seed in the winter, storing it on the stalk. In the barn until the winter, the sanfoin stalks keep it hollow, there are few ears or seeds that touch one another, and the spirits have room to fly off by degrees, the air entering to receive them.

The only way I have found to imitate and equal this is to winnow it from the sheet, and then lay a layer of wheat straw (or if that is wanting, of the very dry thrashed hay) and spread thereon a thin layer of seed. Thus I stack it, layer upon layer, six or seven feet high (and as much in breadth). And then I begin another stack. Let there be straw enough and do not tread on the stacks, and by the seed mixing with the straw both will be kept cool and the seed will come out in the spring with as green a color as when it was put in – and not one seed of a thousand will fail to grow when planted. A little barn room will contain a great quantity in this manner.

I have had above 100 quarters of clean seed thus managed in one bay of a small barn. I do not wait to winnow it clean before I lay it up in the straw, but only pass it through a large sieve, and with the fan blow out the chaff and winnow it clean in the spring.

This field thrashing requires extraordinary fine sunshiny weather, which some summers do not afford at the season for thrashing the greatest quantity of seed. For it is but a small part of the day in which the seed can be thrashed clean out. Those who have a small quantity of it carry it into the barn early in the morning (or even in the night) while the dew is on it, for then the seed sticks fast to the ear. As it dries they thrash it out and if they cure it well, they have sometimes generally good seed...but generally the hay is spoiled.

If there is a great quantity more than can be presently thrashed, it is usually laid up in mows or ricks like corn is. Then if it is carried in during the dews or damp, the hay is sure to be spoiled (if not both hay and seed). But even if the hay is dry, there is trouble: when it is taken up dry, the seed comes out with a touch and the greatest part is lost in the pitching up the cocks, binding and jolting in carrying home.

Labor management lessons from the ants, best practices of labor management; the invention of a wagon-mounted crane

Yet there is one method of saving all the seed good and the hay too by carrying it unthrashed to the barn – to rick it in a particular manner. I[282] happened to have a great crop on 150 acres (and

[282] Tull's words were, "A person," but we believe that this person is most likely Jethro Tull for two reasons: first, he is very good at giving credit to others for their inventions, innovations and ideas – with the exception of himself. He rarely crediting his own experience because he believed it would have reduced the credibility of his testimony. It is highly unlikely that any neighbor would have invented such a device, and very likely that the man who invented the seed drill and new

methods of harnessing horses would have invented such a device. Jethro Tull was always reducing the necessity for labor through mechanization.

Jethro Tull improved the efficiency of his labor by providing superior tools to them so that one person could do the work of a hundred or thousand, and thus allowed humans to approach the efficiency of those greatest farmers, the ants. Indeed, it is not only the way labor is used, but the tools available to them that determine the productivity of a farm.

No other creature is better at intuitive labor management than the ants, and though they have very few tools much can be learned from them in how we manage our own human and domesticated animal labor. After some observation on the behavior of ants, Bert Holldobler and Edward Wilson discovered that to improve the colony's efficiency, the ants employ both specialized and unspecialized labor and successfully demonstrate the superiority of employing both specialized and unspecialized labor over employing either one alone.

"The advantage of ants comes to the fore in the arena of labor efficiency. Consider the following scenario. A hundred solitary female wasps are pitted against an ant colony with the same number of workers, also all female. The two aggregations nest side by side. In a typical daily action, one of the wasps digs a nest and captures a caterpillar, a grasshopper, a fly or some other prey to serve as provender for her offspring. Next she lays an egg on the prey and closes the nest. The egg will hatch into a grublike larva, which will feed on the insect provided and in time emerge as a new adult wasp. If the mother wasp falters in any one of the serial tasks up to the sealing of the nest, or if she tries to perform them in the wrong sequence, the entire operation fails.

Nearby an ant colony, functioning as a *social unit*, overcomes all these difficulties automatically. A worker starts to dig a chamber to expand the colonial nest, larvae will eventually be moved and fed to produce additional members of the colony. If the ant fails at any step of her sequence, all the necessary tasks will probably be finished anyway, so that the colony will continue to grow. A sister worker will simply move in and complete the excavation: other sisters can be counted on to transport larvae to the chamber, and still others to bring food. Many of the ants are 'patrollers.' On stand-by status, these individuals travel restlessly through the corridors and rooms, addressing each contingency they encounter, switching back and forth from one task to the other as needed. They complete the sequence of steps more reliably and finish in less time than could solitary laborers. They are like gangs of factory workers who move back and forth among the assembly lines according to momentary need and opportunity, improving the efficiency of the overall operation." –Pages 9 -10, *Journey to the Ants*.

Holldobler and Wilson go on to explain that solitary insects ("unspecialized labor") are better able to take advantage of the opportunities of marginal territories and emergency scenarios whereas colonial insects ("specialized labor") is better able to capitalize the resources of ideal territories and standard operating conditions.

The scientific farmer can do better than the intuitive ants. When the farmer has few laborers, they will do best to emulate the wasps and ensure that all their labor is unspecialized, given complete tasks and authority to complete those tasks from start to finish. On a small farm, every day is an emergency, a new scenario of problems and solutions that requires the full attention of empowered employees. But the farmer with many laborers does best to emulate the ants and divide their labor into specialized and unspecialized gangs, and will limit the authority and objectives of

by weather being delayed until wheat harvest so that most laborers were reaping) was forced to a contrivance of getting it in as follows:

[**See drawings describing the wagon crane at the end of this chapter** –A.B. & M.C.]. Two wagons had each a board with a hole in it that was secured by iron rods to the sides. There was a crane that a man could lift set into the hole by means of a pole that slid into the hole in the board. This pole was reinforced with iron. This pole allowed the crane to turn all around, and was 10 feet, 4 inches long. Its arm was 4 feet, 8 inches long and braced, and had a triple pulley at the end of it – at the end of the rope was a hook.

About 40 sheets were brought, each capable of holding 150 or 200 pounds weight. These had knots or buttons at the corners and middles (made by sewing up a little hay in the knots until the knots were as big as apples). No buckles or any other thing was sewn to the sheets because they would have torn the sheet. Half of these buttons had strings tied to them for tying up the bundles: these sheets were spread among the cocks, filled two persons and then tied up by two other persons.

the specialized labor to the incomplete task to which they are assigned: a specialized gang will harvest the tomatoes, another specialized gang will bring the tomatoes back to the barn, and a third package the tomatoes, a fourth bring the tomatoes to market, and so on...each gang having the authority to ensure that the raw materials they receive are adequate (in example, if the boxes are too heavy to carry, the intrafarm transport gang may tell the harvesters to not fill them so high), and the responsibility to provide the raw materials required for the next gang (in example, the intrafarm transport will be held responsible to bring the tomatoes undamaged to the barn). The farmer with much labor will also make gangs of unspecialized labor with the authority to observe and direct the entire production line: these "managers," if organized properly, will improve the efficiency of the entire farm by preventing any interruption to the work of any other gang.

The purpose of managers is not to increase the efficiency of labor (that is the purpose of tools and machines), but to serve the needs of the labor whose work they oversee, to understand what factors affect their efficiency. A good, scientific manager will identify the needs of the labor and serve them even before the labor is themselves aware of their need. An assembly line of automobiles demonstrates this excellently. One worker was found, through the process of statistical analysis of their work, to be significantly less efficient than his coworkers. After performing more observation, the manager found it was because the laborer did not know he needed glasses, and was not aware that he was taking more time than his coworkers to undertake his task because of it. When the manager provided the man glasses to correct his vision, his efficiency exceeded those of his coworkers. A scientific manager will also be able to identify strengths and weaknesses of their laborers and assign them to proper tasks: a manager observed that one of his laborers was always making up rhymes and singing about the product he was making, and reassigned him to marketing where he served the company better (earning more revenue per labor hour) than on the production line.

Jethro Tull in the introduction to the First Edition explains the malice of his labor. Such labor is good for little work: the manager must serve the laborer, and the laborer must serve the company ownership. When either the manager does not serve the labor or the labor does not serve the company, the company suffers. By finding a way to do without the corrupt labor, Tull did the wisest thing possible: though there were hands to hire, Tull was forced to behave as if there weren't any for hire. Such malicious hands as those are worse than no hands at all. We have included more discussion of scientific labor management later. –A.B. & M.C.

There was also a light ladder made of fir wood, wide at the bottom, the top of it fastened by a piece of cord to the brace of the crane[283].

Hitch the hook of the lower pulley to the filled sheet and by a little horse at the end of the pulley rope, draw it up sliding up along the ladder (it is up in a moment). Then the man who is below hitches the crook of the pulley to the lower round of the ladder, and the loader above pulls up the ladder form the ground until the wagon is filled with another sheet. The wagons are lengthened by cart ladders before and behind to more easily accommodate the sheets. When 12 or 15 of them are loaded, fix a rope the front and back of each wagon to secure the sheets from jolting and hold the sheets down and in place. The loader pulls out the crane and puts it in the next wagon. One wagon is loading while the other is emptying; both the loading and emptying wagon are serviced by a wagon crane.

It is inconvenient to take out the sheets by prongs by hand, but pulleys easily pull two or three sheets together. One wagon is always going to the field or coming home. This contrivance makes more expedition than one would imagine: three loads have been loaded and sent off in the same time this way while a single load of hay has been loading, binding and raking in the next field through the common way.

Use of a cane mounted on a rick pole to make a monstrous, 44 foot tall rick, expeditious and low-cost, but a barn, if it could be afforded, would be better. Also, such large ricks are more likely to suffer wind damage

I will not relate the manner of making a rick of this seed in the of monstrous dimensions by a sort of mast pole 44 feet high with a 10 foot crane at the top (which has made the same expedition) because I think that where such a quantity of hay is, and when it can be afforded, Dutch barns with moving roofs are far better. Such a rick is troublesome to thatch and the wind has more power to blow the thatch off so high in the air than if it were lower.

Only reserve for the barn what sanfoin seed can be stored in the barn, as the seed may spoil in some years

Neither would I advise anyone to reserve much more sanfoin for thrashing than their barn will hold because, though sometimes it brings the greatest profit by thrashing, it is some years apt to be blighted.

Yield of seed: 16 bushels per acre expected, 40 bushels per acre possible; sale of hay increases total revenues, as does a polyculture of barley or other small grain

I have been told by my neighbor that he had a crop of 40 bushels of sanfoin seed on an acre, but the most profit that I ever took notice of was on half an acre that was drilled very thin and had no crop of grain with it. By this advantage, it produced a good crop of seed the next year after it was

[283] This fir ladder could be replaced by a modern pallet: it is a firm, light device that the machine can grab hold of without fear of damaging the load, while simultaneously dividing the weight of the load evenly for the machine. –A.B. & M.C.

planted and the third year, this half acre produced (as was tried by a wager) within a trifle of 16 bushels of seed that was sold for 2 Pounds and 10 Shillings. The thrashed hay of it was sold for 1 Pound and 2 Shillings. There was also a very good aftermath which was worth the charges of cutting and thrashing so that the clear profit of the 1 year of this half acre of ground amounted to 4 Pounds and 2 Shillings. It was remarkable that at the same time the rest of the same field (being in all 10 acres) had a crop of barley sown on 3 plowings, which (the summer being dry) was offered to be sold at 1 Pound per acre.

Grazing on sanfoin reduces yields; sanfoin is different than grass, which more easily regrows its leaves

I believe the greatest part of the sanfoin that is grown is spoiled by being indiscreetly fed to sheep. I have never suffered sheep to come on sanfoin except between mowing time and All Saints Day. And there is so much danger of spoiling sanfoin by the fraud of shepherds that I knew a gentleman that bound his tenant never to suffer any sheep to come thereon – by this means his sanfoin continued in perfection much longer than usual than sanfoin that is suffered to be fed on by sheep.

The damage of sheep is occasioned by merely by suffering them to continue feeding it too long at a time – especially in the spring, for then the sap moves quick and must be depurated by the leaves. And, as the sun's nearer approach accelerates the motion or ferment of the juices, more food is received by the roots. But, for want of leaves to discharge the recrements and enliven the sap with nitroaerious particles (the sheep devour the buds continually as fast as they appear) the sanfoin's vital flame (if I may so call it) is extinguished, the circulation ceases, the sap stagnates and then it decays.

Natural grass is not killed by constant feeding because no sort of cattle can bite it so low as to deprive it of all its leaves. It is like eels, more tenacious of life than the rest of the genus, and will send out leaves from the very roots when reversed, as is too often seen where turfy land is plowed up in large furrows.

But let the sheep eat sanfoin never so low, and in a short time, without continuing thereon, or cropping the next buds which succeed those that have been eaten, and the plants will recover to grow again as vigorously as ever. And, if with a spade, in the winter, you cut off the sanfoin heads a handful deep and take them away (together with their upper earth), the wound in the remaining root will heal and send out more heads as good as those cut off if those second heads are preserved from cattle until they attain a bigness competent to bear leaves sufficient for the use of the reviving of the plants. Yes, I have seen plants of sanfoin cut off in the winter a foot deep and the earth of that depth taken away, and the remaining rot recovered and grew to an extraordinary bigness...but this was preserved from cattle at first.

Sanfoin is more profitable than clover because sanfoin does no damage to corn if planted in polyculture, but clover can spoil barley and other grains

I esteem sanfoin to be much more profitable than clover because sanfoin is never known to do any perceivable damage to corn amongst which it is planted, but clover will often spoil a crop of barley and I have known that the crop of barley has been valued to have suffered more than 4 Pounds per acre damage by a crop of broad clover's growing amongst it in a wet summer. In a dry summer,

both sorts of clover are apt to miss growing, and if they do grow and the next summer proves very dry, it fails on most sorts of land – though it was vigorous enough to spoil the barley in the year it was sown. At best, it is of but very short duration and therefore it is not to be depended on by the farmer for maintaining their cattle (which the broad clover will also kill by causing them to swell – unless great care is taken to prevent it). Broad clover is esteemed foul feed for horses. Hop clover is gone out of the ground sooner than broad clover. I never knew it cut more than once: indeed, cattle are never swollen by feeding on it because it affords very little feeding for them, except when the land it grows on is very rich.

Sanfoin enriches the ground it is planted upon by the action of its heavy taproot; for this matter, radishes and other heavy taproots will do the same and some of these taproots are more valuable than sanfoin

Sanfoin enriches the ground it is planted on, though a crop is taken off yearly. The poverty of poor slate land (lying upon slate or stone) generally proceeds from the thinness of it, and if it were thicker, it would be good land. Much of this soil is dispersed amongst the crannies or intestacies of the slate and stone to a great depth, it is reached by the tap roots of sanfoin, but cannot be reached by the roots of corn and therefore, when constantly kept in tillage, is of small value. But, such land is greatly improvable by sanfoin (even when sown in the common manner). Poor slate land, when it has borne sanfoin for 6 or 7 years, being plowed up and well tilled, produces 3 crops of corn before needing to be sown with sanfoin again.[284]

Rich arable and was planted with sanfoin and mowed annually with very great crops. It was drilled in 9 inch rows, with 6 gallons of seed to an acre. One crop of it was sold at 4 pounds per acre, this after about 7 years and in full perfection was plowed up by a tenant, and continued many years after to be so rich that instead of dunging or fallowing it for wheat, they were felt compelled to sow upon it barley, and upon the barley stubble wheat, and feed the wheat with sheep in the spring to prevent it from being too luxuriant.[285]

If sanfoin is not to be permanent, to remove it the land must be very well tilled

The land must be well tilled at the breaking up of the old sanfoin, or else the first crops of corn may be expected to fail. I once knew a tenant who, the last year of his term, plowed up a field of sanfoin that would have yielded him 3 Pounds per acre, but thinking to make more profit of it by grain, he sowed it with white oats upon once plowing. It proved a dry summer and he lost his

[284] The sanfoin's heavy tap root will break hardpan and aerate the soil beneath it. For that matter, so will daikon radishes, and radishes will yield a more valuable crop –A.B. & M.C.

[285] Though we have seen land become luxuriant enough that our landlords became afraid it was too rich, we have never seen land become too rich for crops through the horse hoeing husbandry. The fear of land being too luxurious comes from experience with land overfertilized with manure: manure (and all salts) will kill plants. The well-balanced nutrition that the horse hoeing husbandry offers to plants will never kill them, no matter how luxuriant the soil gets. The soil will become better able to yield all kinds of fruits, vegetables, grains, fungi and other crops suited to the temperature and moisture, but the soil will never exclude one kind of plant. –A.B. & M.C.

plowing and his seed, for he had no crop of oats and was forced to leave his land as a fallow to his successor.

Many more instances there are of this failure of the crop of grain after sanfoin has been broken up and not well tilled.

When sanfoin is grown old, it is usually followed by barley or small grains, but turnips can tolerate what sanfoin is not well tilled better than small grains

When sanfoin is grown old and worn out (as it is said to be when the artificial pasture is gone and the natural pasture is become insufficient for the number of plants that are on it to be maintained) and is so poor that it produces no profitable crop, it is thought proper that the ground is plowed up and sown with corn. The most effective way to bring it into tilth speedily is to plow it up in the winter with a four coultered plow, and make it fit for turnips by the following season. And if the turnips are well hoed (and especially if given to sheep while in the ground) it will be in excellent order to be sown with barley the following spring. Then it may be drilled with sanfoin among the barley.

It is not necessary to plow up sanfoin and replant the field: hoe the aisles and provide the sanfoin new food; it is possible to hoe every aisle once every two years (every other aisle per year), but better if all hoed at once

But it is not necessary to plow it up and replant. If you perceive that there is a competent number of plants alive and tolerably single – be they ever so poor – you may recover them into flourishing condition in the following manner without replanting: first, pulverize the whole field in aisles of about 36 inches with the four coultered plow, leaving between every two of them 48 inches unplowed. When the turf of these intervals cut by the four coultered plow is perfectly rotten, hoe the soil with any sort of plow to change the whole surface of it (which should be easily done if the first plowing was undertaken correctly). The poorer the land is, the more hoeing will be required, and the oftener it is hoed properly the first year, the stronger the sanfoin will become and the more years it will continue good without a repetition of hoeing.

Expense of hoeing is not great

The expense of this is not great: in hoeing an acre in this manner 9 times, the plow travels no further than it must to plow an acre once in the common manner.

Why sanfoin enriches soil: it brings to the surface food out of the reach of other plants

All the experienced farmers know that land is enriched by sanfoin but do not agree to the reason why. They agree on the effect but not the cause.

Some are of the opinion that it is because the sanfoin takes a different sort of nourishment to that of corn, but I know that is disproved in my Chapter on Crop Rotation where it is shown that all plants in the same soil must take the same food.

Mr. Kirkham thinks that sanfoin has no collateral or horizontal roots in the upper part of the ground where the plow tills for corn, and therefore has no nourishment from that part of the soil that feeds the corn. This would be a very good theory if it not utterly contrary to facts – as everyone may see who observes the roots of sanfoin.

But Mr. Kirkham is close to the truth. Large sanfoin has large roots that are very long and descend more than 20 feet deep. Now, if we allow that the top 6 inches of the soil equals in nourishment the 24 inches below it, the sanfoin does receive less than 10% of its sustenance from the upper parts of the soil.

Large sanfoin draws the greatest part of its nourishment from below the reach of the plow, and what part it does receive from the staple is overbalanced by the second crop (or after-lease) eaten by cattle on the ground. This is different from corn, which is very nearly entirely maintained by the plowed part of the soil.[286]

For though the under layers of soil are much poorer than the upper, those lower layers have never been drained by any sort of vegetable and affords very good nourishment to the first roots that come there. In such land whose poverty proceeds from the rain's carrying its riches too quickly down through the upper layers to the lower layers, those lower layers are richer for receiving what the upper layers let pass unarrested. In light poor land, the water carries with it the top soil lower than it does in strong land. In strong land, the lower layers of soil are poorer than in light land.

It is well known that many estates have been much improved by sanfoin and therefore there is no occasion to mention particulars. Only I will take notice that the first harvest in England was in Oxfordshire and cost 140 pounds per year, and was sold for 14,000 Pounds. This first planting I hear continues to be of the same value. It is the same planting that that Mr. Kirkham mentions.

Another farm of 10 Pounds annual rent (which, while arable) was likely to have been undone by the tenant had it not been planted with sanfoin by the owner. Later, it was rented for 110 Pounds per year and proved a good bargain! These estates consisted of thin slatey land, which, before it was planted with sanfoin, was valued at 2 Shillings per acre and some parts of it at 1 Shilling per acre (as I have been informed) and yet oxen are very well fattened by the sanfoin it produces.

It is not disputed that sanfoin improves the land values of the owner and the profits of the tenant, but Mr. Kirkham is wrong concerning the reason for this. Sanfoin improves land values and profits more in England than in foreign lands on soil of equal goodness because sanfoin is best suited to the bad laws of England.

Supplement of the Fifth Edition

Nutritional Analysis of Sanfoin Seed

Sanfoin is still a "new" crop in the process of introduction and comparatively less is known about it than other hays and seeds. We undertook laboratory testing to learn more about the nutritional value of the seed on April 11, 2008. Analysis of sanfoin seed for animal feed indicated it was an amazing source of protein, with many other minerals present. We have reproduced the results below for those nutrients we had tested for. The Hay table is reproduced and citation fully provided in the Chapter on Animal Husbandry.

[286] Also, sanfoin will pull water and other nutrients to the surface from the depths of the soil to feed itself, its neighboring and its subsequent crops. –A.B. & M.C.

Nutritional Values of Sanfoin

	Sanfoin Hay	Sanfoin Seed
Macronutrients		
Calories (kcal/kg)	683.4	369.2
Moisture	0.00%	8.20%
Crude Protein	14.0%	27.6%
Fat	*	5.2%
Crude Fiber	24.00%	17.10%
ADF	37.0%	22.9%
NDF	50.8%	30.1%
Minerals		
Calcium	1.57%	0.33%
Phosphorus	0.28%	0.65%
Iron	0.0174%	0.0177%
Zinc	0.0038%	0.0061%
Magnesium	0.20%	0.21%
Manganese	0.0056%	0.0064%
Copper	0.0012%	0.0025%
Selenium	0.2400%	*
Potassium	1.97%	0.26%
Cobalt	0.0000%	*
Sulfur	0.2400%	0.1700%
Vitamins		
Vitamin A, IU	*	*
Vitamin E, IU	*	50.00

The seeds were welcome feed for the animals it was tested on, and we found good success in using sanfoin as a protein and calcium supplement, and as a component of a mixed grain feed. We tried feeding both with breaking the seed and without breaking the seed, and found breaking the seed to be unnecessary for digestion (as it is necessary with flax and some grains) or palatability.

Modern sanfoin husbandry: notes from Dr. John Frame of the UNFAO

Dr. John Frame of the United Nations Food and Agriculture Organization has undertaken to inform the public on growing sanfoin in his article, *Onobrychis viciifolia Scop.* Published on the internet

(http://www.fao.org/ag/AGP/agpc/doc/gbase/data/Pf000347.htm). His excellent work we have provided a summary of here as it provides the most modern understanding of sanfoin and assists the farmer in undertaking Tullian management.

DESCRIPTION

Pubescent perennial with many erect or sub-erect, hollow stems, 60–80 cm or more, arising from basal buds on a branched root stock. After defoliation, branches develop from auxiliary buds on the stem nodes of the remaining stubble. Leaves pinnate with 5–14 pairs of obovate leaflets and a terminal leaflet. Stipules broad and finely pointed. Numerous pinkish red melliferous flowers, borne in erect, conical racemes on long auxiliary stalks. Root system consists of a deep tap root with a few main branches and numerous fine lateral roots bearing most of the rhizobial nodules. Common or single-cut sainfoin flowers mainly in the year after establishment and thereafter for many years, as this type is very persistent. Giant or double-cut sainfoin lacks persistence and flowers in the establishment year and thereafter for only 2–3 years; it has longer erect but less dense stems than common sainfoin. Flowers cross-pollinated, mainly by honey bees; the flattened, indehiscent seed pods contain a single kidney shaped seed, 4–6 mm, dark olive to brown or black in colour. The proportion of hard seeds in harvested seed crops can be 15–20 percent. Number of seeds kg-1: 50 000 (hulled or podded) and 67 000 (dehulled). Average 1000-seed weight: 20.0 g (hulled) and 14.9 g (dehulled).

DISTRIBUTION

Distributed in parts of warm-temperate Europe and Asia, and on dryland, calcareous soils in western North America. Cultivated in some Mediterranean environments, e.g. southern Italy.

CHARACTERISTICS

Growth: Performs best on deep, well-drained calcareous soils at pH levels of 6.0 and above. It has vigorous seedling growth. Thin dry soils require irrigation to improve forage yield. Adapted to warm temperate climes (Frame, Charlton and Laidlaw, 1998). Erect growth habit, suited to infrequent cutting for conservation (hay or silage) rather than grazing. Longevity varies with ecotype or cultivar.

It has a spring to autumn growth period, and seasonality of growth varies from the single flush of growth of the common type to the double flushes of the giant type. A rest period is required in late autumn to allow plants to build up the organic reserves in the roots needed for winter survival and initiation of spring growth. It has excellent drought resistance because of its deep-rooting characteristic, and is intolerant of prolonged flooding.

Compatibility in mixture: Non-aggressive grasses such as timothy (Phleum pratense) or meadow fescue (Festuca pratensis) are compatible. The addition of white clover or birdsfoot trefoil can be advantageous in stands cut for hay and aftermath grazing. Wheatgrasses (Agropyron spp.) are suitable as companion grasses for dryland conditions (McGinnies and Townsend, 1983; Griggs and Matches, 1991).

Temperature: Sainfoin has a wider optimum temperature range for germination and early seedling growth than most other forage legumes (Smoliak, Johnston and Hanna, 1972). Periods of high temperature adversely affect subsequent yields, especially following defoliation, since the plant's ability to support high metabolic rates is reduced (Kallenbach, Matches and Mehan, 1996). Winter cold can reduce plant persistence (Jefferson et al., 1994). High reserves of N in legume roots during winter are believed to aid cold hardiness (Volonec and Nelson, 1995).

Light: The sainfoin canopy utilizes incident radiation less effectively than alfalfa because of a lower leaf area index (LAI) and less erect growth habit. Flowering is favoured by long daylengths.

Water supply: In the absence of irrigation, annual rainfall of at least 330 mm required (Miller and Hoveland, 1995). Water use efficiency, at 15–18 kg DM mm-1 evapotranspiration, is high in spring, equaling that of alfalfa (Bolger and Matches, 1990), but is lower than that of alfalfa later in the season. Irrigation in dry periods aids yield and plant persistence.

Nitrogen fixation: Colonization of sainfoin roots is by rhizobial strains common to other legumes from the same (Hedysarae) and related (Galegae) tribes. Rhizobial inoculation of sainfoin seeds is needed when sown onto land that has been free of legumes for several years. A suspension of crushed nodules from another crop has sometimes been used for inoculation.

Nitrogen fixing efficiency is less than that of alfalfa or red or white clovers, since sainfoin requires about 20 mol CO2 to fix 1 mol of N2 compared with about 10 mol CO2 for the other legumes (Witty, Minchin and Sheehy, 1983). Energy availability may be the limiting factor since sainfoin allocates less assimilate for leaf production and LAI than does alfalfa.

BREEDING

It is cross-pollinated, mainly by honey bees (Apis mellifera), with chromosome numbers of 2n-2x-14 for diploids and 2n-4x-28 for tetraploids. Breeding objectives include improved forage yield, persistence and tolerance of grazing.

Cultivars: Modern bred cultivars do not rigidly align with one or other of the two main original types, common or giant, but are more flexible in their characteristics. Named cultivars include Melrose and Nova (Canada); Remont and Renumex (United States of America); Othello (Australia); Incoronata, Vala and Zeus (Italy); and Fakir (France).

A seed crop can be taken in place of a main hay crop of common sainfoin , or following a hay cut in giant sainfoin, which flowers and seeds twice in a season. Seed yields can reach 1450 kg ha-1 (Hoveland and Townsend, 1985).

Using the Fodder Plant Seeds Regulations for the United Kingdom as an example, certified and commercial seed require a minimum germination of 75 percent and a maximum hard seed content of 20 percent by number of pure seeds. The required analytical purity is 95 percent by weight for certified and commercial seed. The maximum permissible content of seeds of other species is 2.5 percent by weight for certified and commercial seed, and 1.5 percent for the higher voluntary standard of certified seed.

AGRONOMY

Establishment: A well-cultivated, uniform and firm seed bed is required for good results. It is best sown direct for successful establishment, but can be undersown in a cereal crop. On dryland in western Canada, seeding sainfoin in alternate rows with Russian wild rye (Psathyrostachys juncea) rather than sowing the components in the same rows enhanced persistence because of reduced inter-species competition (Kilcher, 1982). Drilling at 20–30 cm depth is advisable, i.e. about twice as deep as red clover, and covering well with soil. On irrigated land, monocultures are usually sown in spring at 40–60 kg ha-1 for dehulled seed and 80–120 kg ha-1 for hulled. Slower-germinating, hulled seeds are sometimes chosen for situations where germination is only wanted after there has been sufficient rainfall to ensure sufficient seedling development. Much lower seed rates are used in dryland conditions. Seed can be protected from fungal

attack by dressing with thiophanate methyl (Nan, 1995). The addition of a non-aggressive companion grass, e.g. meadow fescue (6 kg ha-1) or timothy (2 kg ha-1) increases stand density and reduces weed invasion.

Nutrient requirements: An adequate status of available soil P is necessary for successful establishment. After removal of hay crops, soil P and K replenishment is required to maintain plant persistence and yield, though sainfoin is tolerant of soils with a low P status (Miller and Hoveland, 1995). Liming may be necessary to sustain soil pH at 6.0 and above.

Weeds: Sainfoin monocultures lack competitiveness against weed invasion compared with sainfoin grass stands. Serious infestations of perennial weeds should be controlled by herbicides before soil cultivation...

...Pests: Sainfoin is resistant to many of the pests that attack other forage legumes. Significant pests noted in the United States of America are: Rhizobium-nodule-eating weevil (Sitona scissifons); Lygus bugs (Lygus spp.); and the sainfoin bruchid (Bruchudius unicolor) (Gaudet et al., 1980).

Diseases: Compared with many other legumes, sainfoin is relatively disease resistant. It can be adversely affected by clover rot (Sclerotinia trifoliorum) and sometimes powdery mildew (Erysiphe trifolii) or verticillium wilt (Verticillium albo-atrum).

Forage production: Variable, as DM yields may range between 7 and 15 t DM ha-1 depending upon growing conditions. Yields are about 20 percent lower than those from alfalfa, contributory factors including a lower LAI, a less erect canopy structure and less efficient N2 fixation.

NUTRITIVE VALUE

This is largely determined by stage of growth at time of utilization since nutritive value falls with increasing plant maturity and associated stemminess; data from Quebec, Canada, are shown in Table 1.

Sainfoin is protein and mineral rich in comparison with grasses, but its Ca and Na concentrations are lower than in other major legumes. Its mineral composition is shown in Table 2... A notable feature of sainfoin is the concentration of condensed tannins in the leaves. Hence its forage does not cause bloat in animals, and the tannins also protect protein in the rumen, thus enhancing the supply of amino acids for absorption in the small intestine of ruminants (Waghorn et al., 1990).

Both grazed and conserved sainfoin or sainfoin-rich forages are highly acceptable, leading to high animal intakes of forage (e.g. Griggs and Matches, 1991).

TABLE 1:

Stage of growth	Crude protein (g/kg)	Cell contents (g/kg)	Neutral detergent fiber (g/kg)	Acid detergent fiber (g/kg)	Digestability (g/kg)
Flower bud	146.1	582.4	417.6	296	636
10% flowering	114.4	524.7	475.3	344.7	591
Full flowering	102	491.9	508.1	369.6	557

TABLE 2:			
Constituent (g/kg)	Stage of growth		
	Flower bud	10% flowering	Full flower
Ca	13.8	15.3	15.7
P	2.5	2.8	2.8
K	21.2	19.5	19.7
Mg	1.8	2	2
Na	0.18	0.19	0.18
S	2.4	2.5	2.4
Constituent (mg/kg)			
Mn	53	58	56
Zn	38	42	38
Cu	11.9	12.6	11.6
Fe	189	222	174

UTILIZATION

Grazing management Rotational rather than continuous stocking is best for stand persistence and production. Sainfoin cannot tolerate overgrazing during the growing season and plant persistence benefits from a 6-week rest period from grazing before winter. The accumulated forage can then be grazed after the plants have become dormant. Common sainfoin is more tolerant of grazing than giant sainfoin. Modern cultivars have been bred for better persistence and regrowth after defoliation.

Conservation management Sainfoin is highly suitable because of its upright growth habit and its pattern of regrowth from auxiliary buds after defoliation. Shattering and loss of nutritious leaf is a hazard if haymaking is prolonged. Because of a lower buffering capacity i.e. resistance against pH reduction during the ensilage process, sainfoin herbage has a better ensilability than alfalfa.

ANIMAL PERFORMANCE

Sainfoin gives highly satisfactory individual animal performance. Among other legumes, only white clover was superior to sainfoin as judged by lamb growth (Ulyatt, 1981b).

MAIN ATTRIBUTES

It is a productive protein- and mineral-rich legume suited to calcareous dryland soils, and responds to irrigation on shallow soils. Condensed tannins in the leaves prevent bloating in ruminants and also improve the efficiency of protein metabolism. It has high intake characteristics.

MAIN SHORTCOMINGS

It is slow to establish, and not adapted to a wide range of soil and environment conditions. It is unsuited to intensive grazing.

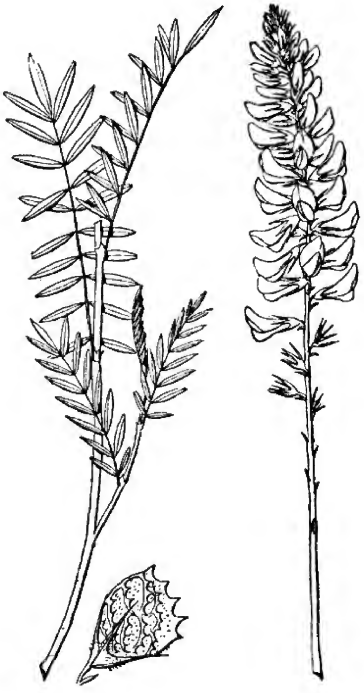
MAIN REFERENCES

Gervais (2000); Frame, Charlton and Laidlaw (1998); Miller and Hoveland (1995).

Identification of sanfoin through pictures

Besides this excellent work by Dr. Frame, we have also here provided some pictures to identify sanfoin, for those unused to it from the United States Department of Agriculture.

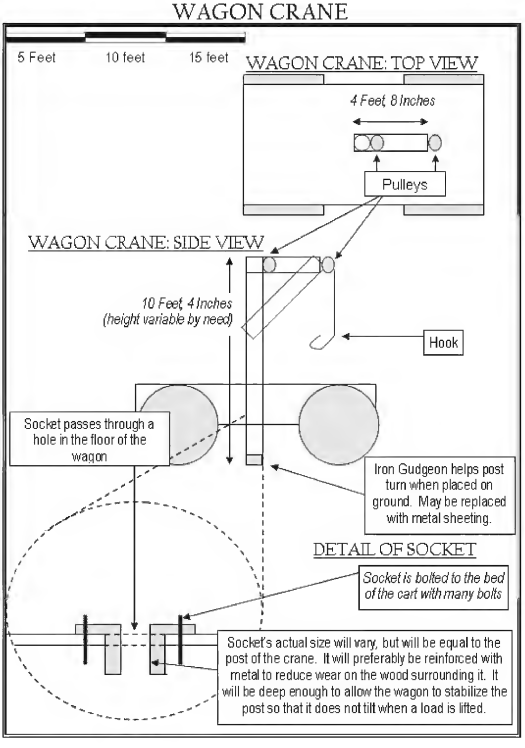
Illustrations: Sanfoin Identification
Sanfoin leaf and seed (Left), and flower (Right)





(SOURCE: USDA Plant Guide: http://plants.usda.gov/plantguide/doc/pg_onvi.doc)

Illustration: Jethro Tull's Wagon Crane



CHAPTER FIFTEEN:
OF ALFALFA (LUCERNE)

Alfalfa is also known as Lucerne, is a "Medical" herb; introduced in America by Spanish, who learned of it from the Arabs and kept the name

"La Lucerne" is that famous medical herb so much extolled by the ancients. The high esteem they had of its use appears by the extraordinary pains they bestowed upon its culture.[287]

Alfalfa regrows quickly after cutting

Its leaves resemble those of trefoil, it bears a blue or purple blossom very like to double violets, produces a pod like a screw that contains seeds about the bigness of broad clover (though longer and more of the kidney shape). The stalks grow more perpendicular than any of the other artificial grasses that I know. It is slender and full of knots and leaves, and is very nearly equal in bigness from bottom to top. When cut, if vigorous, the stalks will spring out again from the stubs immediately below where the scythe parted them – which makes them the sooner ready for another mowing, an advantage which no other grass has.

Alfalfa is like a shrubby tree, has taproot deeper than most other plants, longer than sanfoin

It has a tap root that penetrates deeper into the Earth than any other vegetable She produces, and though one alfalfa root will be much more taper than another towards the upper part of it, it is sometimes seen that a single hoed plant of it has many of these perpendicular roots, some of them springing out from the very branches of its crown.

Its roots are abundantly longer than the roots of sanfoin: I have one that measures very near 2 inches in diameter; those which are higher than the ground have a bark like a tree. Upon this account, and by its stalks springing up again just below the place where cut off and by the woody hardness of its stalks, when they stand too long without cutting, it seems that alfalfa is of nature approaching to that of a shrubby tree.

Alfalfa is the only hay in the world that can pretend to excel or equal sanfoin. I have known instances when alfalfa has met the high praises of the Romans, yielding quantities that seemed incredible to the vulgar. I forbear to relate them, but leave it to be confirmed by the experience of others when it becomes frequent in England. Alfalfa is much sweeter than sanfoin or any other natural grass. When hoed, it may be given to cattle green for six months, but then care must be

[287] In America, Alfalfa was introduced by the Spanish, who learned how to grow alfalfa from the Arabs, and kept the Arabic name. It has this distinct disadvantage over Sanfoin: it has too high a protein content and can kill animals with bloat. There are many forages that have this danger, and harvesting at the proper stage of growth (for Alfalfa, before the flower, or just as the plant begins to flower), or curing the hay can reduce or eliminate this risk.

taken to prevent their swelling by its lusciousness and not to give them too much at once until they are accustomed to it.

The quantities of alfalfa seed annually imported and sown without success should not discourage people from continuing its importation. Rather, it shows that is more need of a successful way of planting it in England than further recommendations to make the attempt. Yet I conclude that there is no hope of making any improvement in its culture here.

The bad methods of the Romans

I wonder if anyone who attempts to plant it here has read in Columella and other authors a description of the manner in which the old Romans planted it. They chose out the very best land that was both pinguia and putris[288], they dunged and tilled it to the greatest perfection, laid it out in beds (as we do for onions and asparagus) and sowed it very thick for the miserable reason that its thickness would kill the grass. The beds were harrowed very fine before sowing (which was at the end of April) and the seed needed to be speedily covered because the sun's heat would spoil it.

But with what instrument it was covered? After sowing, the ancient Romans said the place should not be touched with iron. *At medica obruitur non arato, sed ligneis rastrellis.*[289] Alfalfa seed is covered not with a plow, but with a little (or light) wooden harrow. Two days work (of a team) were spent on this harrowing of one acre. Sometime after it came up, they scratched the alfalfa again and again with the same wooden instrument (this was called serration) then by runcation they weeded it over and over, *ne alterus generis herba invalidam medicam perimat.*[290] Lest other grass should kill it whilst it was weak. The first crop they let stand until some of the seed shattered to fill the ground yet fuller of plants, after that they might cut it as young as they pleased but had to be sure to water it often after cutting. Then, after a few days when it began to spring, they repeated their runcation and so continuing to weed out all the manner of grass for the first 2 or 3 years, it would bring 4 to 6 crops per year and last 10 years.

The English farmer makes 40 Pounds per acre on asparagus or cabbage plants with half the labor and expense that was bestowed on an acre of Roman alfalfa!

We do not know the price of hay and grass in Italy while the Roman Empire was in its glory and Rome, then the metropolis of the world, drew the richest of all parts to there, but to justify the labor their prices must have been very great indeed! Yet then of course, the Romans had not only servants but a plenty of slaves for whom they had not enough employment, and this might have lessened the cost of this tedious method of planting: when the Romans were brought down to the level of other nations and were in danger of becoming slaves themselves, when the lands of Italy came to be cultivated by Italian hands only, they found things more necessary to employ them with than serrations and runcations of alfalfa!

The labor was better bestowed in getting bread for themselves than hay for their cattle. They were so bigoted to all superstitions of their ancestors that they were content to lose all use of that most beneficial plant rather than attempt to cultivate it by a new (though more rational) method when they were unable any longer to continue cultivating it in the old way.

[288] Fertile and crumbly soft –Translation by Aaron Brachfeld.

[289] "Plowmen to heal and crush not, use only wood harrows..." —Translation by Aaron Brachfeld

[290] "To destroy the unwanted plants, second to grow" —Translation by Aaron Brachfeld

Thus, as I take it, superstition as chased alfalfa from the Roman lands and so little of it is planted there that beyond the alps I could not find one whole acre of it.

Alfalfa in France, Switzerland and England

Alfalfa makes such a great improvement in the sandy lands of the south of France that when the land is well prepared and very clean they will sow it alone in March at Michaelmas as we do clover. Their sowing it at those seasons is a double advantage: first, it saves the labor of watering it, which would be impracticable for so many thousands of acres as there are planted. Secondly, those seasons being much moister than that wherein the Romans sowed it, the grub has opportunity of eating more of it at its first coming up and often the frost kills some of it. Thus, the ground is left less overstocked, saving the cost of thinning later.

The summers there are much drier than in Italy so that the sun scorches up the natural grass and suffers it not to come to a turf until after some years. This gives the alfalfa further advantage when competing against the grasses.

But as that natural grass increases, the crops of alfalfa are proportionally diminished and though is said to last 10 or 12 years, it is only in perfection a very few years. It is at best on their richest lands in a kind summer, when they have with 7 harvests 10 tons per acre (as I have computed by some reports from the inhabitants of Pezenas). Yet this amount of production is extraordinary, as I observed myself that most of their usual crops made a thin swarth.

When the ground begins to be turfy and hard, many of the alfalfa plants die and the rest send up few stalks. The people know this is the destruction of it, and therefore I have seen some of them in that case half-plow it, thinking thereby to destroy the turf, and this does for some time strengthen the alfalfa plants, but it so much strengthens the grass also that the turf grows stronger and there is no remedy but to plow it up and make the ground clean, and replant it.

In more northern climates where it rains oftener, the ground sooner becomes hard, and in the land otherwise most proper for alfalfa, the grass grows infinitely faster – and will be as strong a turf in 2 years as in the hot countries in 10. Upon this account about Paris, even near the walls, they plow up alfalfa and plant sanfoin instead because it endures the grass and hard ground better, though it brings only one harvest per year (two at the most).

And in many places in France and Switzerland, I have seen alfalfa in the corners of vineyards, not above 2 or 3 perches together, which they will at any expense have to cure their horses when sick, since they cannot obtain by their agriculture quantities sufficient to maintain their horses with alfalfa as an ordinary food (there is too much rain and too little of the sun's violent heat to prevent the speedy increase of grass amongst it).

How then can we expect success in sowing it in England where rains are even more frequent and the sun is weaker? There is not one year in ten that the natural grass here is scorched. In our rich land the grass comes to a turf very soon and poor land will not by the common sowing bring alfalfa to any perfection (even if no grass should annoy it).

I have here seen a part of a meadow breast-plowed and when the turf was dead, dug up and planted as a garden. After it had been drilled with carrots, hoed and made in all appearance perfectly clean, it was sown with alfalfa, which came up and flourished very well the first year and indifferently the second. After that, the grass came and the alfalfa grew faint, and by the fourth year there was no more left, except just to show here and there by a single poor stalk that there had once

been alfalfa there. Of these, one plant was cleared of grass and sent up an abundance of stalks for two years afterward, and then when the grass returned, dwindled again.

I have often tried it in the richest parts of my garden and constantly find that, however vigorously it grows at the first, it soon declines when the grass appears among it. This happens sooner, the richer the land is, unless the spade or hoe prevents the grass.

Here has also been many fields of a poorer whitish soil sown with it, which are not very subject to be overrun with grass as rich land is. And though these soils were so well tilled that scarce any grass appeared, during the many years the alfalfa lived upon them, it never grew to any perfection. There was not one crop worth much more than the cutting of it, and it was always poor, thin and short. By what intelligence I can get and by all my experience, every soil in this Island is too rich, too poor or too cold for the alfalfa to become common.[291]

With old husbandry, alfalfa requires replanting 3 years after establishment; with hoeing husbandry alfalfa does not need replanting

I believe everyone who will inquire into the matter will find that among the great quantities of alfalfa that have been sown in this Kingdom in that manner, never any of it was known to continue good and flourish more than 3 years. And that, on the contrary, never any one plant of it in any warm soil, cultivated by the hoeing method, was known to fail here or in any other country so long as the hoeing (or digging about it, which is an equivalent thing) was continued with the proper repetitions.

A multitude of such hoed plants have I known and are now to be seen in both poor and rich lands. Therefore it seems possible that thousands of English acres are capable by the hoeing method to produce crops of alfalfa every year for an age. For as the greater moisture and less intense heat of this climate are upon the accounts mentioned injurious to alfalfa, yet this is only injurious to alfalfa sown and cultivated in the common method because, our climate is, upon the same accounts, beneficial and advantageous to hoed alfalfa.

Alfalfa does poorly with too much or too little heat and moisture

In hot countries when the summer is drier than ordinary, the sun so scorches alfalfa that they have fewer and poorer crops than in moister summers. But in the driest summers I have ever known in England, hoed alfalfa yielded the most crops.

Our summer days are longer and have more of the sun's warmth and less fiery heat, the sun cherishes but does not burn alfalfa – or any other long tap-rooted plant in England.

Hoeing prevents too much soil moisture and too little

The well hoed soil being open receives and retains the dews, the benign solar influence is sufficient to put them in motion but not to exhale them from thence. The hoe prevents the turf – which would otherwise by its blades and roots intercept and return the dews back to the

[291] It is now more common than sanfoin in Britain, due to improvements in breeding, changes in climate and changes in market demand. –A.B. & M.C.

atmosphere – with the assistance of moderate heat. So that as this method secures alfalfa from the injury of a wet summer and also causes the rain to sink down more speedily and disperse its riches all the way of its passage (otherwise the water would be more apt to stand on the surface, chilling the soil, keeping off the sun and preventing the air from drying it).

When the surface is dry and open, alfalfa will bear a great degree of heat or grow with an average heat.

Alfalfa can grow under some circumstances at a rate of 1 inch every 6 hours

I have seen a very large single plant of it, which had not been hoed for two years before and was on September 27th laid bare to observe the manner of its tap root, upon being covered up again sent out more stalks in October than it had done in the whole summer before. This plant grew vigorously until a great snow fell in December, which also preserved the verdure of them, until it was melted away and a black frost came after it and killed those stalks. It is probable that this plant sent out immediately new fibrous horizontal roots which grew apace to extract the nourishment from this new made pasture in proportion to the new growth of the stalks. It was measured and found to grow in height 3.50 inches in a night and a day, or one inch every six hours.

And it has been my observation that this plant in hot and cold countries thrives in both with a much greater or less degree of heat and moisture when it is hoed or has plenty of nourishment, which hoeing always gives it. And a little heat above and the moisture alone (which is never wanting to the tap root), that plenty of food enables it the better to endure the extremes of heat or cold.

Alfalfa is cold hardy, more so than rosemary

We need not much fear the dangers of English winters because alfalfa will endure those which are more rigorous. In the principality of Neufchatel, the winters are so severe as to kill the rosemary left abroad, yet alfalfa survives them there. This proves it is more hardy than rosemary, which is planted for hedges in England, and there is here scarce twice in an age a frost is able to kill it.

One alfalfa plant has produced 22 winters and was still strong at the time of publication

I have one single alfalfa plant in a poor arable field that has stood the test of 22 winters, besides feeding sheep at all seasons, and is as strong as ever! What quantity of hay this plant yearly produces cannot be known because at those times that cattle are kept from it, the rabbits constantly crop it, it being sweeter than other grasses. [292]

[292] Rabbits will eat alternately high protein and low protein foods, and do prefer alfalfa for their high protein needs. The rabbit is unusual in that it will pass two kinds of feces as well: soft feces and hard feces. The rabbit will usually reingest their soft fecal matter because of the inefficiency of their digestive system, passing out a final hard fecal matter that is not reingested. To discourage rabbits from the hay, predators should be encouraged: rabbits prefer wide open spaces that they can observe the various hawks, foxes, coyotes, snakes and other predators approaching

But this happens to be fortunately situated where it is not entirely destitute of the benefit of hoeing. It is in an angle where every time the field is tilled, the plow goes over it in turning from the furrows of one land and one head-land, but it is after the plow is lifted out of the ground and turned up on one side so that the share only breaks the turf very small all around it without plowing up the plant. Yet it has escaped so narrowly that the fin of the plow share has split it into four parts, three of which remain and grow never the worse, but the fourth is torn off and the wound healed up.

Hardiness to various climates depends on breeding and the tolerance of individual plants; those with thick bark are more hardy

By the extreme hard winter that happened about the year 1708 or 1709, some of the alfalfa in Languedoc was killed. Yet this was no argument of its tenderness, but rather the contrary because then all the olive trees and walnut trees were there killed, though the greatest part of the alfalfa escaped unhurt. And I did not hear one walnut tree was killed that winter in England! Perhaps those in France were accustomed to much hotter summers and were unable to endure the rigor of the same winter that could do no harm to the same species in England, where our winters do not seem to exceed some of theirs in cold so much as their summers do ours in heat?

The extremes are not so far asunder here, the same degree of cold may to our plant seem tepid, which those in Languedoc must seem rigorous, differing in a more remote degree from the opposite extremity of heat in summer.

And besides the difference of heat and cold in different climates, there is another difference more necessary to be observed: there is a difference in the hardiness of individuals within the same species. The same frost that kills a faint languishing plant of alfalfa will be despised by a robust one, which being well fed by the hoe, becomes a giant clothed and fenced with a thick bark that renders it impregnable against all weather. Its rind is to it a coat of mail or buff impenetrable by frost, but the unhoed is generally small and weak, its thin bark exposes it almost naked to the frost. And, it being for want of sufficient pastured starved and half dead already, it is more easily killed by the cold.

Alfalfa grows large only with proper nutrition – from hoeing

I formerly lived some years in Languedoc, where many hundreds of acres of alfalfa are planted. And I never could find a large plant in all those hundreds of acres, except where the land had been tilled and sown with corn. There, indeed, those plants that remained (as always some do) grew to an extraordinary bulk, and one of those single tilled plants did seem to produce a greater quantity of stalks than 20 of such as had not been plowed up. And as there were no large plants among the unplowed, so there were no small among the plowed ones. The same thing has been observed in all other places where alfalfa has been plowed.

them. Planting blinds for these carnivores reduces predation by rabbits and larger herbivores. –A.B. & M.C.

The best soil for alfalfa? That which is hoed. Even the worst soils are improved sufficiently through hoeing. Even apples, peaches and cherries, which originate in very different climates, can be brought to fruit in England on the same soil under the same conditions if well fed and well bred

In Wiltshire, several fields of it stood some years without coming to substance to be of any value, thought he land was whitish and no grass appeared among the alfalfa. Therefore its poorness was thought to proceed from the soil being improper, but when the soil had been broken and sown several years with corn, and afterwards lain down with sanfoin, all the alfalfa plants which remained (and there were many!) grew large and strong, shooting up a yard in height soon after the sanfoin was cut. And if there had been a competent number of them undestroyed by the plow, they would have yielded crops of extraordinary value, where before plowing it grew but a few inches above the ground.

It seems that in this sort of land the soil grows stale before the alfalfa grows to be a tenth part of its stature. But it is remarkable that the tillage transforms those alfalfa plants from dwarfs to giants and then they are able to contend with and conquer strong plants like sanfoin, when before they had been plowed they were unable to resist the depredations of a few hairy spires of grass.

Since tillage can thus recover alfalfa after it has long languished in the lowest ebb of life, and restore it to health, youth and vigor, and augment its stature even after it has passed the age of its full growth, to what bulk it would arrive at when regularly planted and hoed from its infancy to maturity without any check to stunt it?

We can never know how poor a soil will bear this plant unless tried by the hoeing culture. It is wondrous how so great a man as Dr. Woodward should imagine that the difference of soil should be the reason why apples in Herefordshire and Cherries in Kent succeed better than in other places when in truth they are seen to prosper as well as almost all over England where planted, cultivated and preserved.

I suppose the Doctor took from Virgil, for when the Roman soldiers had as a reward of their rebellion obtained the lands of their country from the lawful owners, their product would have disappointed all expectation of profit if those lands should have been planted with ivory or frankincense. I am sure the Doctor did not consider how different the soil of these mentioned counties are to those climates from whence apples and cherries were originally brought. It must be greater than between that of any two counties in England! The reason why no more of these large plantations are made is probably for want of sufficient laws to secure their fruit to the owners.

As peaches require a good wall to help them fruit regularly and well, alfalfa production is improved through climate modification: hot gravel, rich dry sand or other warm non-clay soils are best

I believe plants are more altered as to their growth by being cultivated or not than by changes of climates differencing in degrees of latitude. I say in their growth, not always in their fruit: for though a peach tree well cultivated in a standard will grow here vigorously and be very beautiful, yet its fruit will be of little value unless it is planted against a good wall.[293] So alfalfa, unless cultivated upon well exposed gravel, will yield very little seed in England.

[293] In Colorado, advances in breeding have made some peaches resistant to harsh conditions. A story may be heard in Fort Collins, the location of the State's agricultural university, of a retired

The soil to plant it on is either a hot gravel, a very rich dry sand or some other rich warm land that has not an under stratum of cold clay, nor is too near the springs of water. For if the soil beneath is of a cold nature, which I take to be occasioned by its holding water, the alfalfa will not long prosper therein of whatever sort the upper stratum of soil may be.

The temperature of the soil may be guessed at by the vegetables a soil naturally produces: fern and the like, which Mr. Evelyn observes to indicate a soil subject to extremities of heat and cold, and therefore condemns such a soil as accursed. I agree to the sentence as far as relates to cold, but am not satisfied of its abounding heat and am sure I know some lands subject to fern which is very far from being barren, which when well cultivated suits with vegetables – though not alfalfa.

In hot countries, alfalfa grows best near rivers

Alfalfa in hot countries grows best near rivers where its roots reach the water, mitigating the excessive heat of the climate. But here the heats are so moderate that if alfalfa roots are in water (for it is that which makes the soil cold) it diminishes too much the just proportion of heat upon which alfalfa depends.

The natural poorness of a hot gravel may be compensated by manure, more heat and the benefit of the hoe.

The best season to plant alfalfa is in early spring. Plant very thin and hope the frost thins it more: only 1 to 2 pounds of seed per acre are necessary. Plant at 1/2 inch depth. Do not plant in autumn, as the winter will kill too many

The best season for planting it in England I take to be the early spring, for then there is always moisture to make it grow and not heat enough to dry its tender root so as to kill it by melting it.

If they should take so early a season for the common way of sowing it, the ground would become hard or stale before the sun were high enough to bring it forward. But there is no danger of this inconvenience to that where the hoe has come and opened the ground as often as there should be occasion.

I have planted it at the end of February and though there followed a very hard frost in March which killed some part of it, what remained was of a sufficient thickness. I believe the quantity of seed planted might be after one to two pounds per acre. The depth it was planted at was half an

Professor whose life ambition was a winter proof peach. He bred it over the decades of his long career in the lawns of his city house. Five peach trees he grew to his satisfaction. At the time of his death, one was given to a close friend (who related this story and showed the editors what was left of the tree) and four were donated to the University. While they were being transported to the University gardens for study, the truck suffered a severe accident and killed the trees. The last tree was successfully planted the same day in the lawns of the friend, but upon learning of the accident, the friend tried to donate his to the University and set out to dig it back up... but rodents had torn the tree apart and killed it. Notwithstanding such setbacks faced by breeders, it is possible now to obtain even almonds that can withstand winter temperatures in Colorado thanks to the multigenerational efforts of courageous – and more fortunate – breeders. –A.B. & M.C.

inch, which upon trials I have found best for most sorts of fine seeds. I do not approve of planting it late in the autumn because our long winter might kill too much of it and weaken the rest in its tender infancy.

Because alfalfa has larger roots and yields more crops than sanfoin, about the same number of alfalfa plants should be seeded per acre

The hoed plants of alfalfa having larger roots, and yielding more crops than those of sanfoin, reason would seem to require that fewer alfalfa plants should be needed per acre. Alfalfa roots exceed sanfoin in bigness and length by a great proportion. Though they require better soil and more frequent aid from the hoe, by their extraordinary quick growth they receive a speedier relief from it as the roots of sanfoin do. Thus, by reaching deeper in better soil and being better hoed, alfalfa receives from a square perch of ground nourishment in proportion double to that whereby its roots exceed those of sanfoin in bigness, and I do not see why we should not leave the number of alfalfa plants double to the number of those of sanfoin. Yet, the nourishment it requires in hot or cold environments requires trials on location to determine the exact number of alfalfa plants properly placed on a square perch.

Better to plant fewer than too many

To err in falling somewhat short of the just number is better than exceeding it.

Where alfalfa stand at 4-5 inches asunder in the rows, it is observed that thought he intervals between the row as are wide, the plants are much larger and produce more than those that stand in the outside row (the outside grounds being clean), and especially those at the end of the outside rows (that is, the corner plants) are largest of all. I need not say that had all other plants as much room and tillage as the corner ones have, they would be as large and produce each as much hay for those which stand perfectly single in places by themselves. Single plants produce more than corner ones, and the longer and larger roots there are, the more nourishment they are capable of taking, as has been previously shown.

And it must be likewise observed that the crop will be produced in proportion that it receives, for if the most gigantic alfalfa plant remains a few years without proper nutrition, it will little by little cease to produce more than a few sickly stalks, and only enough leaf to show its species. But if it is hoed, it will reclaim its pristine strength and yield as great a crop as ever. But if cultivation is delayed, it will die. The vastness of its root avails it nothing unless it has food in proportion to it.

Most disease is related to malnourishment

[294]Hence it appears that most fatal disease incident to alfalfa is related to its starving and that it rarely suffers any illness if well fed. Plants which are malnourished seldom arrive at the full potential of their growth or age, malnourishment prevents their fertility even in the prime of their lives and kills them before they have lived out half or perhaps the tenth part of their days. How long

[294] These statements are generally true for all animals, plants, fungi and microorganisms. –A.B. & M.C.

the life of a malnourished plant might have been nobody knows unless a plant could be found to die when well fed, but a well fed plant is tenacious of life.

Even beheading them will not necessarily kill a well fed plant: I have cut off the heads of some of my alfalfa to try, and though I could not find that any one that would sprout again, my sanfoin did.

It is therefore necessary that our rows be placed at such a distance that their intervals may be wide enough for the hoe to raise an artificial pasture sufficient to sustain the number of plants in them.

Undertake trials to learn the exact distances for your land, but begin with aisles of 30 inches or more to allow regular hoeing

Whoever shall make trials of this husbandry (for that is all I propose to others) I would advise them to begin with rows that have aisles of 30 inches, for if they begin with much narrower distances, they may be by that means disappointed of success. Though it is possible that in the future farmers should find a way to hoe them at somewhat narrower distances, the loss of a few perches of ground would not be much. And those perches are not wholly lost, since the roots of these plants may be proved to extend much further horizontally than from row to row at that distance! And the wider the intervals are, the more soil will be tilled in a perch of ground: six rows, which will be apart by 30 inches distance, admit the hoe to till more soil than nine rows at 22 inches distance from each other.

Wider rows and aisles allow the farmer to eliminate grass, which would decrease yields greatly

And besides which argument for fertility, it is not proper that every time of hoeing, the plow should come very near to the plants unless when grass comes amongst them. And then they may be in 30 or 33 inch spaces and be perfectly cleaned in this manner: plow a good furrow from each side of every row, and then with the harrows or other instruments proper for the purpose going across them, you will pull out both earth and grass from between the plants. Then, at after a convenient time, plow these furrows back again to the rows, this will in a manner transplant the upper part of the roots and bury the grass that is not dead and lying open to the sun that which is. Then the harrow can break it more and level it, and go once over it with a light roller to the end that the hay may be raked up cleanly.

Remember that apple trees are not planted close together because they grow larger; initially the field will look barren, but maintain a thin planting density until the alfalfa grows to be mature

I am aware of the common prejudice of people who have never seen a plantation of these plants in perfection: they are apt to form to themselves the idea that such small ones as they have been used to see are sufficient to make a crop and plant with narrower rows. But they might with equal reason imagine the same of apple trees at a year's growth, which are less than these at the same age and plant a thousand trees in the room proper for one.

Estimating Yield: MODERN STATISTICAL ANALYSIS MATHEMATICS

The quantity of a crop may be determined and proved greater than fancy from measuring the weight or number of stalks in a perch of ground and multiplying the product by the total area of the field.[295]

[295] It is better to sample 1% - 15% of a field in this manner: divide the field into 100 units of similar size and randomly select 5-15 of them for sampling. Cutting the stalks to weigh them may reduce the crop, but counting the stalks and measuring 5%-15% of the stalks within the sample will not impact the total yield significantly. Though a minimum sample of 5% is preferred, 1% is acceptable. The reason for this minimum proportion (1%-15%) is due to the statistical ability to perceive variance in the sample

Typically, all else being equal, a larger sample size leads to increased precision in estimates of various properties of the population, though the results will become less accurate if there is a systematic error in the experiment. This can be seen in such statistical rules as the law of large numbers and the central limit theorem. Repeated measurements and replication of independent samples are often required in measurement and experiments to reach a desired precision. A typical example would be when a statistician wishes to estimate the arithmetic mean of a continuous random variable (those which are non-integer are "continuous," for example, the height of a person is continuous, yes/no answers or categorical answers are integers). Assuming that they have a random sample with independent observations, and also that the variability of the population (as measured by the standard deviation, σ) is known, then the standard error of the sample mean is given by the formula:

$$\sigma / \sqrt{n}.$$

Standard Error = (Standard deviation) / (square root of sample).

It is easy to see that as n (the sample size) becomes very large, this variability becomes small: eventually, when n=N (the population size) and all the data have been sampled, there can be no standard error in sampling. However, because n is square-rooted, slightly increasing n initially results in vast reductions to the standard error.

But how big of a sample is big enough?

A typical statistical aim is to demonstrate with 95% certainty that the true value of a parameter is within a distance B of the estimate: B is the confidence interval, the confidence of a sample. It is an error range that decreases with increasing sample size (n). In this case, when B = 95%, it is described by saying that "there is a 95% confidence interval." This typical statistical aim is generated arbitrarily: for some samples, B should exceed 99.9%, for others, B may be allowed to exist much below 25%. Sometimes this is effected by the cost of sampling: it is sometimes not worth the price to know more accurate information.

The rule of thumb for (a maximum or "conservative") B for a proportion derives from the fact the estimator of a proportion, p = X / n, (where X is the number of "positive" observations – those that result in data – and n is the sampled population) has a (scaled) binomial distribution and is also a form of sample mean.

The definition of a Bernoulli distribution that has a maximum variance of 0.25 for parameter p = 0.5 is assumed because the central limit theorem states that as the size of a sample of independent observations approaches infinity, provided data come from a distribution with finite variance, that the sampling distribution of the sample mean approaches a normal distribution. So, the sample mean

I undertook such measurements and found...

Date	Note	Value when weighed:	*sh.*	*d*
April 14th	One single unhoed plant of alfalfa had 31 stalks		23,	0
April 14th	The stalks of one single hoed plant of alfalfa		56,	0
April 24th	Unhoed alfalfa plant, dried		6,	6
April 24th	Hoed alfalfa plant, dried		14	6

X/n has maximum variance 0.25/n. For sufficiently large n (usually this means that we need to have observed at least 10 positive and 10 negative responses, again an arbitrary set of numbers), this distribution will be closely approximated by a normal distribution with the same mean and variance. Using this approximation, it can be shown that about 95% of this distribution's probability lies within 2 standard deviations of the mean and will form a 95% confidence interval for the true proportion. Thus, the rule of thumb for obtaining B-95% comes from the definition of two standard deviations from the mean.

$$(\hat{p} - 2\sqrt{0.25/n}, \hat{p} + 2\sqrt{0.25/n}) = (\hat{p} - B, \hat{p} + B)$$

If we require the sampling error ε to be no larger than some bound B, we can solve the equation

$$\varepsilon \approx B = 2\sqrt{0.25/n} = 1/\sqrt{n}$$

To give us

$$1/\varepsilon^2 \approx 1/B^2 = n.$$

Using this understanding,

B = 10% ↔ n = 100 B = 5% ↔ n = 400

B = 3% ↔ n = 1,000 B = 1% ↔ n = 10,000

In general, if a population mean is estimated using the sample mean from n observations from a distribution with variance σ^2, then if n is large enough (typically ›30) the central limit theorem can be applied to obtain an approximate 95% confidence interval of the form

$$(\bar{x} - B, \bar{x} + B), B = 2\sigma/\sqrt{n}$$

If the sampling error ε is required to be no larger than bound B, as above, then

$$4\sigma^2/\varepsilon^2 \approx 4\sigma^2/B^2 = n$$

if the mean is to be estimated using P parameters that must first be estimated themselves from the same sample, then to preserve sufficient 'degrees of freedom,' the sample size should be at least n + P.

This sampling method is good not only for predicting crop yield, but for measuring labor output, animal output, market prices, and analyzing any of the other data the farmer is constantly confronted by. It is especially useful in trials to examine whether, in fact, a method is better than another. When trialing the New Deep Hoeing Husbandry, employ statistical analysis to learn whether it outperforms the old method: it is not necessary to trial it on your whole land. Trial it on even 1% of your land, and you will earn great data that will tell you how it will do on 100% of your land.

Sample sizes of 1% - 15% are good rules of thumb. When the farmer makes n = 100, sampling 10 plots will yield a perfect estimate. But when the farmer is measuring something that cannot be broken into 100 parts, if the farmer does not wish to perform the math to identify how large of a sample to take, they can aim for 1% - 15%.

In this light, Tull's sample is likely accurate–A.B. & M.C.

When 18 inches of length in a hoed row, including five different plants were measured they weighed 1 pound and a half avoirdupois.

Date	Note	Value when weighed:	*sh.*	*d*
April 24th	18 inches of hoed row, dried to hay		28	6

When one foot of two-rowed hoed beds, being 160 stalks of alfalfa six or seven years old were assessed, they weighed 2 pounds green. The same dried on the 9th of May weighed came to more than: 31sh. 6d

These six or seven year old plants amount to more than three tons per acre!

This I am certain of, that the least competent number plants will bring the greatest number of crops. Since I see the stalks of a single hoed plant grow higher in 15 days than one amongst near neighbors does in a month.

Alfalfa is thinned when more mature than sanfoin because they are likely to be thinned by insects and environmental factors

The greatest difference between the culture of alfalfa and sanfoin is that alfalfa rows should be more grown before the plants are made single in them by the hand hoe, lest the fly should destroy some afterwards and they become too thin. For alfalfa is sometimes eaten by the fly as turnips are, though sanfoin is never liable to that misfortune if sown in the proper season. Alfalfa must also be more frequently hoed in some proportion to the more frequent crops it produces.

Alfalfa is benefited greatly by hoeing, especially in the removal of turf, but do not tolerate well suffocation: be very careful to turn the soil into the aisle, and then back towards the row without putting the soil onto the beds

The hoe plow is the instrument to bring alfalfa to perfection, but then I doubt it must lie still some years, lest the plowed soil injure the hay that is made upon it. And when it is come to a turf and the alfalfa needs renewal, the four coultered plow is the only instrument that can prepare the turf to be killed and cure the alfalfa. This plow must be used in the following manner: turn its furrows towards one row, and from the next, that is, plow around one row and that will finish two aisles, and so on. And the next plowing must be towards those rows, from whence they were turned the first times. Take care that the first furrows do not lie long enough on the rows to kill the plants. The plants can tolerate the suffocation a much longer time in winter than in summer.

More remarks on the bad Roman methods

I shall not go about to compute the difference of expense bestowed in the Roman culture and this, yet it will appear that theirs was incomparably more expensive and that the excess of expense was occasioned by their error in the theory of husbandry.

They sowed it so thick that the plants needed to be very small, and when 10 of them were no bigger than one good single hoed plant would have been in the same space of the soil's surface, they could have but a 1/9 part of the soil's depth that the single hoed plant would have had. The defect of depth would have necessitated a compensation in the extraordinary richness of the surface, and upon this account few lands were capable of bearing their alfalfa.

Their sowing it so late made the first watering necessary and the shortness of the roots required the repeated rigations after the crops were cut, described by Columella in Lib. 2, Cap. 11.

But had it been cultivated by the hoeing method, then the tap roots would have descended deep as a well, and from the springs below have sent up water to the plants, besides what the hoe would have caused the horizontal roots to receive from dews at the surface above. At how much a cheaper rate water is supplied by these means, than by carrying it perhaps a great way and then sprinkling it by hand over the beds, which were made 10 feet wide between path and path for that purpose let anyone judge.

And also what a laborious task it was to pick out the grass with fingers from amongst it in the hard dry ground in the summer after mowing the crop (as Columella directs in his aforementioned chapter) which the horse hoe could have done with ease at a 1/20 part of the expense. However, they did not even give it the same culture with the bidens which would have been much better and cheaper than to cleanse the alfalfa with fingers. Indeed, fingers were made before the bidens, but surely something besides this fact inspired the Romans to hoe their alfalfa with fingers instead of bidens.

Oh! Of course, but surely this is the reason! The biden was made with *iron* and alfalfa had, in those times, an antipathy to iron! After it was sown, the Romans knew that the place must not be touched by that metal. Therefore the seed must not be covered by a plow, nor with iron harrows.

But if they had made trials enough to that half an inch was the proper depth to cover this seed at, even these virtuosi would have been convinced that it had no less antipathy to these instruments than of how deep they were buried. The weight of iron harrows in such fine ground would have been sufficient to bury them at that depth. Had the plow been of all wood, the furrow would have lain never the lighter upon the seed, and if the wooden harrows had been loaded with a weight capable of pressing it down as deep, it would have been no more able to rise than if it had been buried with iron harrows. Even Columella seems insensible to this fact.

It was not sufficient to have the harrows be made of wood, unless they were light ones. It is probable that the plow suffered none to come up and that the harrows were too heavy to allow but a few to sprout, though perhaps they would have had plants enough if they calculated what number were sufficient.

But unless the ground were covered with them at first, it seems they had not the patience to wait until the plants grew large enough to fill it with a barely competent number and thought it not worthwhile to weed and water what they believed to be an insufficient number.

It was expected that the thickness of the plants should help to kill the grass[296], yet upon due observation it is found that when their excessive numbers have brought a famine amongst them, they are forced to prey upon one another and though the stronger survive this trial, even those are so weakened by hunger that they become less able to contend with the grass whose good fortune it was that superstition would not permit the Romans to interpose by attacking it with iron weapons.

[296] This is still a common belief. –A.B. & M.C.

I hope these hints may be improved for the abolition of old errors and the discovery of new truths, to the end that alfalfa may be planted in a more reasonable method than has been commonly practiced. And when the theory is true, it is impossible that the practice should be false if rightly applied. But if it fails of success, such an event would be proof either of misapplication or that the theory is false.

Haying alfalfa is similar to haying sanfoin, but should be harvested in its virginity

Alfalfa should be ordered for hay in the same manner as is directed for sanfoin. But it must be observed that alfalfa is more worsted by being suffered to survive its virginity before cutting, and therefore the richest and most nourishing hay is cut while the stalks are single without any collateral branches shooting out of them. And when they are so, neither blossoms nor even buds appear.[297]

For multiple harvests, hoeing should be employed

Alfalfa sown in the old fashion cannot be easily harvested more than once: for want of a new supply of nourishment, they grow so slowly that when it is high enough to be cut, the blossoms are already blown out and the stalks, though very small, are by now quite woody, hard and dry. Such hay is nothing near so nourishing as it was when it was virgin.

But in alfalfa which is hoed, the last crops of it will, by virtue of the greater quantity of nourishment that it receives grow faster and will be of a height fit to cut before blossoming, and thence, being as young and vigorous, make as good hay as the first crops. Thus, hoeing does not only procure more and larger crops but also better hay.

Remember that grass is the greatest enemy to alfalfa

This is most certain, that unless we can keep our alfalfa pretty clean from the natural grass, we cannot expect it to succeed, let the soil never be so proper.

[297] Commonly now, farmers wait for the beginning of flowering to ensure that the vegetative period is certainly over. If flowers are allowed to blossom, the hay must be cured or else the farmer risks bloating of the animals which will feed upon it, though animals can be made accustomed to the flowery alfalfa gradually. However, this is seen as being better than having not allowed the plant the full length of time required to outgrow its virginity. We do not advocate for waiting for the end of virginity or not, but do argue that sanfoin is a better hay crop because such questions are entirely unnecessary to ask –A.B. & M.C.

Supplement of the Fifth Edition

Alfalfa is the Queen of hays, but sanfoin is King, ryegrass is a jack of all trades

Alfalfa claims to be the Queen of Hays, but certainly then Sanfoin is King. Both present quality products, but, as discussed in the Chapter of Turnips, a decision whether to favor one or the other depends on the nutritional requirements of the animals.

We will presume that alfalfa and sanfoin yield each 3 tons per acre in a given year. On a single acre of alfalfa hay, 1,050 pounds of protein will be produced. On a single acre of sanfoin hay, 1,140 pounds of protein will be produced, an advantage to sanfoin of just about 8%. Yet when kilocalories are considered, alfalfa produces 1,172,772.14 per acre and sanfoin produces 1,859,968.71 per acre, a 37% advantage to sanfoin! Calcium production favors alfalfa, with nearly twice as much calcium produced per acre. And Phosphorus production is equal.

Yet this increasingly complicated decision is made simple by alfalfa's threat of causing bloat to animals, and any reasonable farmer would shy away from alfalfa for that alone. However, that alfalfa is less hardy than sanfoin seals the deal and makes it an inferior feed to sanfoin.

But as to whether sanfoin is superior to ryegrass is difficult to decide, as they each have such distinct advantages that make them incomparable without consideration to the farm's total operation and market prices.

Nutritional Value

Though alfalfa leaves and flowers are delicious and nutritious fresh vegetables for human consumption and important crops for grazing bees on, the feeding of alfalfa hay as animal food is popular as well. This table is reproduced and citations provided in the Chapter on Animal Husbandry.

Nutritional Value of Alfalfa Hay

	Alfalfa Hay
Macronutrients	
Calories (kcal/kg)	430.92
Moisture	0.00%
Crude Protein	17.5%
Fat	1.8%
Crude Fiber	30.00%
ADF	36.0%
NDF	47.0%
Minerals	
Calcium	1.20%
Phosphorus	0.28%
Iron	0.0250%
Zinc	*
Magnesium	0.29%
Manganese	0.0045%
Copper	0.0008%
Selenium	*
Potassium	2.01%
Cobalt	*
Sulfur	0.1300%
Vitamins	
Vitamin A, IU	0.45
Vitamin E, IU	*

Modern alfalfa husbandry from the UNFAO

Dr. John Frame of the United Nations Food and Agriculture Organization has undertaken to inform the public on growing alfalfa in his article, *Medicago sativa L.* Published on the internet (http://www.fao.org/ag/AGP/agpc/doc/gbase/DATA/PF000346.HTM). His excellent work we have provided a summary of here as it provides the most modern understanding of sanfoin and assists the farmer in undertaking Tullian management.

The cultivation of alfalfa was successfully undertaken without this information by Tull, but better understanding the environmental requirements of alfalfa can allow the farmer to compare their farm's environment with the needs of alfalfa to better serve their plants.

Alfalfa, known as Lucerne to Dr. Frame, is an...

...erect or ascending, glabrous perennial, 30-90 cm, with alternate trifoliate leaves ; leaflets, 30 mm, narrowly obovate, toothed in upper third with a mucronate tip; stipules linear-lanceolate, usually serrate. Numerous stems originating from crown buds; as the stems develop, axillary buds formed in lower leaf axils produce further stems which build up a crown of basal buds at their base. Crown is the main source of stems produced after defoliation; axillary buds above ground develop into branches. Deep-rooted, 2-4 m, or more in deep, well-drained soils. About 60-70% of total root mass is in the upper 15 cm of soil profile (Heichel, 1982). Inflorescences are compact racemes up to 40 mm, borne in axils of upper leaves; purple florets, 8 mm, typically papilionacious. Cross-pollinated by various species of bee. Seed pods spirally coiled, glabrous or pubescent; pods turn from green to brown as they mature, and contain 2-5 kidney-shaped, yellow or brown seeds. A proportion of the seeds are hard, probably inversely related to temperature during seed set (Fairey and Lefkovitch, 1991).

Modern cultivars of M. sativa usually contain varying proportions of M. sativa and M falcata genes in their make-up though the sativa gene is generally dominant. The common names of M. falcata are yellow lucerne or sickle lucerne. It is a decumbent, rhizomatous perennial, 30-60 cm, with alternate trifoliate leaves, leaflets being sharply pointed. Roots thinner and more branched than common lucerne. Inflorescences are compact racemes, 25 mm, with yellow florets. Seed pods straight to curved, 2-5 seeds per pod. Hybrids between M. sativa and M. falcata known as sand, hybrid or variegated lucerne (M. media) bear yellow, mauve or purple florets and can be back-crossed with both parents. Seed pods curved or spiral, 3-8 seeds per pod.

The following refers to common lucerne (M. sativa) with occasional reference to the other two species, as appropriate.

Distribution: Widely distributed in temperate zones of the world, e.g. USA, southern Canada, Europe, China, southern Latin America, South Africa. In the USA, an estimated 10-11 million ha have been grown annually in recent years (Barnes and Sheaffer, 1995).

Characteristics: Highest yielding forage legume. Requires deep, well-drained fertile soils to maximise potential. Perenniality and upright growth habit make it a highly suitable crop for conservation as hay, silage or in dehydrated form. Usually productive for 4-6 years. Range of cultivars with differing characteristics has extended its ability to grow in environments from very dry to very cold. Generally grown in monoculture. Has a higher tolerance of saline soils than many other forage species.

Season of growth: Spring to autumn, but main flush of growth in late spring/early summer. Variable in winter dormancy. Winterhardy types suited to cold regions have a longer dormancy period and shorter growing season than the less winterhardy types suited to warm temperate regions.

Temperature for growth: High air temperature of 27 degrees C optimum for seedling growth but optimum declines to 22 C as shoots develop (Fick et al., 1988). Optimum temperatures for root growth, 21-25 C (Kendall et al., 1991). High temperatures reduce forage digestibility due to a decrease in total non-structural carbohydrates (Wilson et al., 1991). Plant hardening for cold resistance increases with declining temperatures from 10 C downwards, completing the process at −1 C to −2 C (McKenzie et al., 1988). The most winterhardy cultivars harden more rapidly with decreasing temperatures and are slower to deharden in spring with rising temperatures than less winterhardy cultivars. During hardening the concentration of soluble sugars increases while starch concentration decreases (Castonguay et

al., 1995) . Lucerne is known to survive temperatures of –25 C in Alaska and above 50 C in California (Barnes and Sheaffer, 1995).

Frost tolerance and regrowth: There are varying degrees of frost tolerance among genotypes, the most tolerant being those with a high proportion of genes from yellow lucerne, e.g. Grimm in North America. The European Flamand (Flemish) and Provence types have only moderate frost tolerance because of lower proportions of yellow lucerne genes, the Provence types being less winter hardy than the Flamand types. In general, the most frost-tolerant genotypes are slower to start growth in spring and quicker to cease growth in winter and so have a shorter growing season. Winter hardiness is strongly associated with low rates of autumn forage production (Perry et al., 1987).

Light: Lucerne is a long-day plant though the minimum photoperiod required to initiate flowering varies among cultivars (Major et al., 1991). Flower number and floral development are also promoted by long photoperiods. Shortening autumn daylengths initiate cold hardening, and in conjunction with low temperatures induce winter dormancy. These effects, together with prior cessation of stem elongation, occur earliest in autumn with the most cold-tolerant types (Hesterman and Teuber, 1981). During periods of rapid growth in the growing season, competition for light within the canopy leads to the dominance of shoots emanating from the crown buds over those initiated from axillary stems (Gosse et al., 1988).

Drought tolerance: More drought tolerant than other forage legumes such as red clover or birdsfoot trefoil (Peterson et al., 1992). Deep-rooting ability is an important factor in drought tolerance and any adverse soil physical or chemical conditions which restrict root growth will reduce drought tolerance. During severe drought, plants become dormant but resume growth when moisture becomes available (Hall et al., 1988).

Water supply: Compared with many forage species lucerne is an efficient user of water supply largely as a result of its deep tap-root system. A linear relationship between available water capacity and yield has been shown (Douglas, 1986). While water use efficiency varies with season, it is normally in the range of 5 to 9 cm evapotranspiration/ha per tonne of forage DM produced (Sheaffer et al., 1988). The less winterhardy genotypes suited to warm temperate regions are more efficient water users than the cold-tolerant types. Water deficit adversely affects shoot production and hence efficiency of light interception by the canopy thus leading to reduced yield (Durand et al., 1989). Many of the physiological functions, such as photosynthesis, respiration and nitrogen fixation, are also adversely affected by moisture stress. In comparison with irrigated lucerne, moisture-stressed lucerne had lower mineral contents in the forage though forage digestibility was higher due to delay in maturity (Kidambi et al., 1990).

Tolerance of flooding: Intolerant of prolonged flooding which adversely affects root development, forage yield and plant persistence. Root and crown rots, e.g. Phytophthora root rot (Phytophthora megasperma), may develop and thus reduce plant populations (Sheaffer et al., 1988). Well-drained soils are necessary in areas with high rainfall or for irrigated crops so as to avoid soil saturation.

Soil requirements: Needs well-drained, deep friable soils with high levels of soil fertility, including a high soil pH, 6.0-6.5, for optimal performance. Soils which are compacted, have indurated layers or are inherently shallow adversely affect lucerne growth and development. Wheel tracking during crop harvesting, or during application of fertilizers or slurry for example, reduce plant persistence and growth vigour partly through soil compaction and partly by plant damage (Sheesley et al., 1974).

Rhizobium relationships: Rhizobial N-fixation in the nodules is by strains of Rhizobium meliloti., distinct strains being required for different lucerne genotypes. Nodules are concentrated on the fibrous roots in the upper soil layer. There is also scope to breed cultivars receptive to a wide range of Rhizobium strains (Barran and Bromfield, 1997). Seed inoculation is essential when introducing lucerne to land without a recent history of growing lucerne. Lack of available Ca at low soil pH reduces Rhizobium activity and root nodulation, and the natural occurrence of R.

meliloti is markedly reduced below a soil pH of 6.0 (Graham, 1992). Lime pelleting of inoculated seed increased nodulation of branch roots at the plant crown in seedlings, thereby increasing nitrogen concentration and dry weight of the shoots (Pijnenborg, et al., 1991).

Ability to spread naturally: Some winterhardy cultivars develop stem-producing rhizomes from the plant crown, while some are 'creeping-rooted', i.e. they produce adventitious stems from primordia which arise from roots (Teuber and Brick, 1988). Winterhardy yellow lucerne has a creeping, rhizomatous habit as have the Spanish 'mielga' lucerne types which are persistent under grazing.

Land preparation for establishment: Well-cultivated, uniform and firm seed bed required for good results.

Sowing methods: The seed is normally drilled after conventional seed-bed cultivations but seed can also be broadcast. When growing lucerne with a companion grass there is no advantage in sowing the two components in alternate drills (Fairey and Lefkovitch, 1994). Sowing lucerne under a cover crop, e.g. wheat, barley, reduces weed invasion and the cover crop provides a cash crop. However, there is a greater risk of poor establishment compared with direct sowing due to competition from the cover crop and so its seed rate and N fertilization should be reduced. The risk is greatest in dryland conditions where moisture can be limiting. Lucerne can be direct drilled (sod seeded) into an existing grass sward or cereal stubble, but this method is not common since it is more risky than conventional seeding methods. Direct drilling is most successful on swards with low-density vegetation when there is adequate moisture for germination and seedling development (Brash, 1983). Dense grass swards can be thinned out by severe grazing, cutting for conservation or by partial chemical desiccation. Guidelines for successful establishment include: control of perennial weeds before sowing ; adequate soil pH and fertilization with water-soluble phosphate; sufficient soil moisture. Control of pests, e.g. slugs, may also be necessary (Byers and Templeton, 1988). Autotoxicity militates against sod seeding lucerne into a thin lucerne stand or reseeding lucerne after a previous lucerne crop (Hegde and Miller, 1990) but disease and/or pest prevalence may also be a factor.

Sowing depth and cover: The optimum depth is 10-15 mm with a light but firm soil cover to promote seed-soil contact.

Sowing time and rate: Spring is normally the best time since temperature and moisture conditions are usually satisfactory for good seed germination and efficiency of Rhizobium action. Lucerne can also be sown conventionally or drilled into the stubble of a cereal crop in autumn, provided there is sufficient time for the plants to develop enough to withstand winter cold and possible frost heaving of the soil. An autumn deficit of soil moisture can be overcome by irrigation if autumn sowing is preferred to spring sowing (Janson, 1975)

Seed rates between 6 and 20 kg/ha are commonly used. Much higher rates of 17-34 kg/ha are used in southern USA due to the occurrence of seedling diseases compared with 10-13 kg/ha used in northern USA and southern Canada (McKersie, 1997). An initial plant population of 135-270 plants per square meter is suggested as a reasonable target (Barnes and Sheaffer, 1995). When sown with a companion grass, non-aggressive species are used, e.g. 2-4 kg/ha of smooth brome grass (Bromus inermis) or meadow fescue (Festuca pratense). Other grasses used include cocksfoot (Dactylis glomerata) or reed canary grass (Phalaris arundinacea) (Sheaffer et al., 1990). Lucerne sown at 3-5 kg/ha in 30-70 cm-wide drills produced high seed yields (Askarian et al., 1995).

Number of seed per kg: Circa 500,000.

Percentage hard seed: A high proportion of hard seed, 30-40 % can be present in seed lots...

...Nutrient requirements: the optimal soil pH for plant development is in the range 6.0-6.5 and so liming is often a key requirement; Mn and Al toxicity are problems in acid soils especially if available Ca levels are low. Adequate P in the seed bed is necessary for seedling development, and in the USA, phosphate is often band-applied below the sown lucerne seed. In soils with a low soil N status a small 'starter' N dressing of 25-50 kg/ha at establishment will

encourage seedling development but thereafter nodulation and rhizobially-fixed N will satisfy plant needs (Hannaway and Shuter, 1993). Because of the high rate of removal of nutrients in conservation crops, replenishment is necessary to maintain production. In particular, large amounts of K are removed and need to be replaced ; K fertilization improves lucerne tolerance to intense cutting management and winter injury (Sheaffer et al., 1986). However, the major nutrients, P, S and sometimes Mg, require replacement too. B and Mo may need to be applied; deficiency of B adversely affects young tissue growth and stem elongation while Mo deficiency reduces the functioning of the nitrogenase enzyme in the N-fixation process. Critical levels of nutrients, i.e. the minimum concentrations within the plant required to produce 90-95% optimum growth, are shown in Table 4. The interpretation of herbage nutrient analyses is clouded by nutrient interactions. For example, increasing availability of soil P increases uptake of Ca, Mg, Na and S but reduces the uptake of K and some trace elements, while increasing availability of soil K reduces the uptake of Mn, Zn, Ca and B (James et al., 1994). The problem can be partly overcome by the use of nutrient ratios, e.g. the diagnosis and recommendation integrated system (DRIS) (Russelle and Sheaffer, 1986).

Compatibility with grasses and other legumes: Compatible with non-aggressive grasses. Different grass species favoured by different countries e.g. smooth brome grass, cocksfoot and reed canary grass are the species most commonly used in mixtures in northern USA (Sheaffer et al., 1990) where mixed stands rather than monocultures are sown although the latter two species are considered to be aggressive towards lucerne. In Europe, timothy (Phleum pratense) and meadow fescue, cocksfoot, and tall fescue (Festuca arundinacea) are among the species used.

Ability to compete with weeds: Relatively low at early establishment phase but improves with the development of the canopy. Sowing a companion grass deters weed ingress though herbicides to control grass weeds cannot then be used. Once established and agronomically well managed, vigorously-growing, dense lucerne stands prevent severe weed invasion...

...Seedling vigour: Initially poor on account of small seed size.

Vigour of growth and growth rhythm: Once established, capable of vigorous growth provided there is high soil fertility, adequate water supply, whether rainfed or by irrigation, and good crop management. Growth is slow in early spring peaking in late spring-early summer. Autumn yield is related to genotype and is lowest for cold-tolerant, winter-dormant cultivars.

Nitrogen-fixing ability: Estimates of annual rates range from 85 to 360 kg N/ha with a wide variation among sites (Witty et al., 1983 ; Heichel and Henjum, 1991). Plant nutrient deficiencies in the soil, excessive soil acidity, a high soil N status, or applied fertilizer N all limit N-fixation due to the sensitivity of the nitrogenase enzyme system to the soil environment. Nitrogen-fixation is markedly reduced though not stopped by high levels of fertilizer N application (Lamb et al., 1995). Defoliation causes a marked decline in N-fixation due to the removal of photosynthate supply to the nodules (Cralle and Heichel, 1981) but also to feedback inhibition since nitrogenous products accumulate in the nodules (Hartwig and Nösberger, 1994); however, nodule growth and N-fixation increase again with new vegetative regrowth. Lucerne requires half the energy of that needed by sainfoin for N-fixation (Witty et al., 1983). In lucerne, 10 mol of carbon dioxide (CO_2) is lost in respiration per mol of fixed N (Sheehy et al., 1984). The main route of N transfer from lucerne to companion grasses is by death and decomposition of below-ground roots and nodules and subsequent mineralisation of this N from the organic matter (Dubach and Russelle, 1994). However the proportion of total N transferred is generally lower than from red or white clover (Heichel and Henjum, 1991). Stress conditions, defoliation in particular, causes senescence of root material.

Response to defoliation: Best suited to an infrequent defoliation regime in which cutting for hay or silage is the main objective. This management allows nutrient reserves within the plant to build up between defoliations and so maintain yield and persistence. Nitrogen reserves in the roots are important in determining the rate of growth after

defoliation, with regrowth drawing mainly from the vegetative-storage protein pool (Barber et al., 1996). In cold regions with relatively short growing seasons, e.g. the northern states of the USA, three or four harvest are taken annually as a rule (Sheaffer et al., 1988) but in warmer, drier regions at least double this number can be taken under irrigation (Barnes and Sheaffer, 1995). Within a growing season, increasing the frequency of cutting reduces yield but increases forage nutritive value. The timing of harvests is best linked to stage of development of the primary growth and regrowths, and an index system based on ten developmental stages from early vegetative through to ripe seed pod has been produced...

...In autumn a rest interval is needed before growth ceases so that carbohydrate and nitrogen reserves can build up to enhance winter-cold tolerance. The dormant forage can then be utilised after onset of winter. If reserves are depleted by late-autumn defoliation the number of crown buds, from which early-season growth is initiated, is reduced. This also has repercussions later in the season since yield becomes dependent on stem axillary buds; these buds are encouraged by tall (10-14 cm) rather than shorter stubble heights at defoliation. Leaving tall stubble at the final defoliation in cold regions can ameliorate frost effects on the soil and retain snow cover which protects crown buds against frost (Barnes and Sheaffer, 1995). Timing of the autumn rest interval is less critical in milder climates, the Mediterranean region; for example, although first-cut yields the following year were reduced by cutting before the first frosts, annual yields were similar to those from stands cut near or after the first autumn frost (Marble et al., 1989 ; Lloveras et al., 1998).

Grazing management: Some form of rotational grazing is required to sustain plant persistence and production. The rest intervals following defoliation replenish the root and plant crown reserves of carbohydrates and nitrogen which are needed for regrowth. Short grazing periods ensure young regrowths are not grazed (Janson, 1982). The duration of the rest intervals depends on the growing conditions which prevail but are likely to be in the 5- to 7-week range. If continuously grazed, defoliation should be lax to prevent over-severe defoliaton and damage to plant crowns. In mixed swards, a highly acceptable grass companion is needed and stocking rate and grazing intensity controlled so as to prevent selective overgrazing of the lucerne (Leach, 1983). Some degree of success has been achieved in the development of lucerne cultivars with improved tolerance to grazing, including continuous grazing (Brummer and Bouton, 1991)...

Suitability for hay and silage: The inherent growth characteristics and good yield response to infrequent cutting make lucerne a highly suitable species for conservation as hay or silage. A succession of cut crops firstly at 10% bloom thereafter and at 5 to 7 week intervals maximises yield, gives satisfactory nutritive value and aids stand longevity (Sheaffer et al., 1988). When making hay or wilting crops cut for silage, it is important to save the nutritious leaf fraction as much as possible during handling since leaf shatter and loss is major hazard during drying. In spite of lucerne's high protein content, low sugar content and high buffering capacity against acidification during silage fermentation, compared with grass crops, high-quality silage can be made using the techniques of wilting, short chopping and the application of an effective additive. Artificial dehydration is also used in order to produce high-quality lucerne cubes, pellets or meal.

Value as standover or deferred feed: Not a common method of utilization but the forage accumulated in the late-autumn rest period – required to build up root carbohdyates and nitrogen reserves – can be utilized soon after winter dormancy has set in.

Feeding value: Rich in protein, minerals and vitamins. Feeding value largely determined by stage of growth at the time of utilization since nutritive value falls with advancing maturity and associated increase in stem :leaf ratio. Cell wall constituents (cellulose, hemicellulose, lignin) increased by 0.16% of dry matter per day with advancing maturity (Keftassa and Tuvesson, 1993) and this decreases forage digestibility. The decrease in digestibility is more

marked in the lower than upper stem fractions and is least in leaves (Buxton et al., 1985). Increasing the number of crops in a season by cutting at earlier stages of growth improves forage digestibility and crude protein content but at the expense of yield (Brink and Marten, 1989; Hesterman et al., 1993). In comparison with grass at similar stages of growth lucerne has lower cell wall and digestible fibre contents but higher digestible cell and crude protein contents (Campling, 1984). It also has higher contents of most minerals of nutritional importance to livestock...Protein-rich lucerne and energy-rich maize make a valuable combination for dairy cow feeding.

Acceptability: Highly acceptable forage to livestock whether as hay, silage, dried pellets, cubes or meal or when grazed at a leafy growth stage. Thus, has high voluntary intake characteristics.

Anti-quality factors: Bloat is a hazard when grazing lush lucerne stands but conventional preventative methods are available e.g. provison of anti-foaming agent such as poloxalene. Lucerne contains oestrogens which reduce conception rates in cattle and sheep if grazed or fed lucerne prior to mating. The oestrogen content differs among genotypes but may be increased in the leaves by pest and fungal attack which is often prevalent in the autumn (White, 1982). Saponin content in the forage has a dual effect of causing adverse haemolytic effects in stock, but also conferring plant resistance to pests (Tava et al., 1993).

Seed harvesting methods: Seed crops are usually direct combined following spraying with a crop desiccant to speed up drying. Correct timing of harvesting is necessary, i.e. when 65-75% of the seed pods are dark brown, to avoid loss of seed by shedding. Guidelines for successful seed production are available (Dunbier et al., 1983); these include a spring hay cut or grazing before crop closure, irrigation as required up to the seed stage, the use of bee colonies for pollination, spraying with fungicides against fungal diseases or with pesticides against insect pests as necessary.

Seed yields: Yields average 750 kg/ha in the main seed-producing areas of the USA, i.e. the western states where the majority of crops are grown under irrigation, but in the midwestern states yields of 50 kg/ha are more typical (Barnes and Sheaffer, 1995). In Europe, an average seed yield is about 400 kg/ha.

Seed quality standards: Using the Fodder Plant Seeds Regulations for the United Kingdom as an example, certified seed requires a minimum germination of 80% and a permissible maximum hard seed content of 40% by number of pure seeds in the sample. Required analytical purity is 97% by weight for the minimum standard and 98% for the higher voluntary standard. The maximum permissible content of seeds of other species is 1.5% by weight for both the minimum and higher voluntary standards.

Cultivars: There is a wide range of genotypes with differing characteristics available, many being the result of mixed ancestry from sativa and falcata types and their hybrids. Winterhardy cultivars, e.g. the Grimm types, are used in northern USA, south-east Canada and other winter-cold regions because of winter dormancy and cold hardiness whereas Mediterranean types more suited to warmer climes have a longer growing season and shorter winter-dormancy period. The basic lucerne germplasm used in present North American cultivars represents a spectrum of winter dormancy due to its derivation from nine world regions (Fairey et al., 1996).

In recent decades there have been notable successes in the development of cultivars with resistance to a number of pests and diseases e.g. cv. Ranger (bacterial wilt), cv. Moapa (spotted alfalfa aphid), cv. Agate (Phytophthora root rot), cvs Vertus and Vernema (Verticillium wilt). There has been a marked increase in lucerne breeding in the USA in recent decades, 440 cultivars having been released beteen 1962 and 1992, with most of the releases in the later years resulting from privately- rather than publicly-funded research programmes (Barnes and Sheaffer, 1995). Because of the numerous cultivars on the market in the USA, cultivar databases such as ALFALFA CATALOG have been compiled (Townsend et al., 1994). This gives general information on the dormancy index and dormancy reference population, flower colour composition and origin together with the resistance levels to the most common pests and diseases. Some

examples of lucerne cultivars are Apollo II, Boreal, Trumpetor, Admiral, Vernal (USA) Angus, Beaver, Drylander, Rambler (Canada), Estival, Europe, Euver, Resis, Sitel, Vela (Europe), Hunter River, Grasslands Otaio (Australasia).

Innovative breeding techniques using different biotechnologies are being increasingly used to develop new cultivars of lucerne – and other forage legumes – with improved N-fixation, nutritive value, and tolerance or resistance to biotic and abiotic stresses McKersie and Browne, 1997)

Diseases: Many diseases can attack lucerne from the seedling to the seeding stages and both foliage and roots can be affected. The diseases may strike individually or in combination and sometimes complexes with other pathogens and pests can occur. Reviews of the major diseases, over 20, of lucerne in the USA are available (Leath et al., 1988 ; Stuteville and Erwin, 1996)...

CHAPTER SIXTEEN: AN ARGUMENT AGAINST THE NEED FOR CHANGE OF SPECIES OR CROP ROTATION

Proving that crop rotation (change of species) is unnecessary through three arguments:

1. Plants of the most different nature feed on the same sort of food
2. All plants rob other plants within their reach of food
3. Soil which is proper to one kind of vegetable once is, in respect of the sort of food it gives, proper to it always.

[298]If any one of these three propositions are true, as I hope to prove all of them are, then it will follow that there is no need to change the species of vegetables from one year to another in respect to the different food the same soil is, though falsely, supposed to yield.

For if all plants rob one another, it must be because they all feed on the same sort of food, and but admitting they do, there can be no necessity of changing the species of them from one soil to another. The same quantity of the same food, with the same heat and moisture which maintained any species one year will do it in any other year.[299]

[298] Chapters 16 through 20 were originally published as a separate, shorter work (a *Specimen*) and their style is much different than the rest of the work. Chapters 16 and 17 are more in the lines of argumentative essays than any technological or scientific exposition, and we have retained this style. –A.B. & M.C.

[299] Crop rotation is now undertaken for two reasons, primarily. The first is for the hygiene of the plants, the other is to improve fertility of the soil, neither of which are necessary.

When a single monocultural crop is grown in the usual way on the same ground year after year, the microorganisms in the soil adapt to the constant environment and overwhelm the plants: thus, a change of species would improve the health of crops by encouraging biodiversity in the soil. However, when soil is tilled in aisles, the diversity is encouraged in the soil that keeps in check the undesirable disease-causing microorganisms and makes the soil less habitable for them. Planting multiple kinds of crops in the soil at the same time also encourages the necessary biodiversity to keep undesirable microorganisms in check.

Farmers will also rotate crops to include those they believe improve soil nitrogen content. These crops, usually beans, peas or other legumes, have a symbiotic relationship with the bacteria responsible for the nitrogen deposition. However, these same nitrogen depositing microorganisms, as discussed previously, can be better encouraged through the tillage of aisles – even when no plants are growing on the field. –A.B. & M.C.

The common opinion is contrary to all these (as it must be contrary to any of them) and since an error in this fundamental principle of vegetation is of very ill consequence, and since Dr. Woodward, who has been serviceable in other respects by proving in his experiments that soil is the food of plants, has unhappily fallen in with the vulgar in this point, his arguments for this error require to be answered in the first place.

Dr. Woodward says in his *Philosophical Trans.* N. 253

"it is not possible to imagine how one uniform, homogeneous Matter having its Principles, or Original Parts all of the same Substance, Constitution, Magnitude, Figure and Gravity, should ever constitute Bodies so egregiously unlike, in all those Respects, as Vegetables of different Kinds are; nay, even as the different Parts of the same Vegetable. That there should be that vast Difference in them, in their several Constitutions, Makes, Properties, and Effects, and yet all arise from the very same Sort of Matter, would be very strange."

Answer: It is very probable that the terrestrial particles which constitute vegetables, though inconceivably minute, may be of great variety of figure and other differences. How else could they be capable of the several ferments, etc. they must undergo in the vessels of plants? [300] Their smallness can be no objection to their variety, since even the particles of light are of various kinds. [301]

But as Dr. Woodward asserts, "that each Part of the same Vegetable requires a peculiar specifick Matter for its Formation and Nourishment; and that there are very many and different Ingredients go to the Composition of the same individual Plants" from hence must be inferred, that the same plant takes in very many and different ingredients. And experimentation, described in previous chapters, has proven that no plant refuses any ingredient that is capable of entering the roots.

Dr. Grew in his *Anatomy of Plants by Microscopial Inspection* found that the outer surfaces of roots was of a spongy substance, and it is well known that no such body can refuse to imbibe whatever liquor comes in contact with it, but will by its spongy porosity absorb any sort of moisture.

Though the terrestrial particles which nourish vegetables are not perfectly homogeneous, most of the various tastes and flavors of plants are made in and by these vessels. It seems that the

[300] Plants are, indeed, composed of many different kinds of atoms and molecules. These they obtain from the soil, and, when harvested repeatedly, can cause deficit in the soil... unless they are replaced by what naturally falls by rain from the oceans (even in the interior of continents, the rain brings microminerals from the sea), what is mineralized from the atmosphere (microorganisms deposit micronutrients suspended in the atmosphere) or eroded from mountains. The farmer who tills well in the aisles fears nothing of soil depletion, and will experience an improvement to their soil over time. –A.B. & M.C.

[301] Though all light is composed of photons (which are neither matter nor waves of energy), there are seemingly an infinite kind of light, vibrating at various unique frequencies. This was recently discovered by Sir Isaac Newton who, in his genius through experiments, understood about physics as much as Tull did about agriculture, becoming the father of the scientific method through his experiments with prisms and colors of light. Newton's body of work remains contemporary to this day, presenting the most modern understanding of the universe in many respects, shedding light on where the science of physics must travel if it is to dig deeper than Newton did. Of course, Newton's book on light (called *Opticks*) and all his work is recommended further reading. –A.B. & M.C.

vessels of plants make the different flavors, because there is none of these flavors in the soil of which they are made until that soil has entered and been altered by the vegetable vessels, as demonstrated in experiments described in previous chapters.

Dr. Woodward says

"That Water will pass Pores and Interstices, that neither Air, nor any other Fluid will; this enables it to enter the finest Tubes and Vessels of Plants, and to introduce the Terrestrial Matter, conveying it to all Parts of them; whilst each, by means of Organs 'tis endow'd with for the Purpose, intercepts and assumes into it self, such Particles as are suitable to its own Nature; letting the rest pass on through the common Ducts."

If the Doctor's plants were so nice in leaving vegetable matter behind, quiet and undisturbed, it is a wonder they would take up the mineral matter as he says they did that killed themselves with salt.

These plants might with much less difficulty have distinguished the mineral matter from the vegetable matter, than they could distinguish the different particles of vegetable matter from one another, and must have been very unwise to choose out the salt (their poison) from the water and soil and leave the vegetable particles behind; none of which could be so improper to them as the salt.

It may be perhaps objected that such like pernicious matter kills a plant only by destroying its roots, and by closing the pores which prevent the nourishment from entering to maintain its life, and that such matter does not itself enter to act as poison upon the sap, or upon the vessels of the body or leaves. But it plainly appears that it does enter and act as a poison, for when some of the roots of a mint, growing in water, are put into salt water, it kills the whole plant – even though the other roots remaining in fresh water were sufficient to maintain it if the other roots had been cut off at the time they were removed into the salt water. Also all the leaves, when dead, will be full of salt.

Or if the juice of a wild garlic be made use of instead of salt water, it will have the same effect, and every one of the mint leaves will have a strong taste of garlic in it.

Dr. Woodward says each plant lets pass through it the rest of the particles that are not suitable to its own nature. In the latter paragraph he says, that each leaves the unsuitable behind for another sort of vegetable. Both cannot be true.

If the latter were true, the change of sorts would be as necessary as it is commonly thought. But if the former is true, as I hope to prove it is, then there is no use of changing sorts in respect to different nourishment.

If in this series of crops each sort were so just as to only take such particles as are peculiarly proper to it, letting all the rest alone to the other sorts which they belonged as the Doctor imagines, then it would be equal to them all which of the sorts were sown first or last. But let the wheat be sown after the barley, peas and oats (instead of being sown before them) and then it would evidently appear, by a starved crop of wheat, either that some or all of those other grains had violated this natural probity, or else that nature has given vegetables no such law of Meum and Tuum[302].

A Charlock could not rob a turnip and starve it more than several turnips can do unless the charlock did take from it the same particles that would nourish a turnip, and unless the charlock devoured a greater quantity of that nourishment than several turnips could take. Flax, oats and poppy could not burn or waste the soil, and make it less able to produce succeeding crops of

[302] Mine and yours. –A.B.

different species unless they exhausted the same particles which would have nourished the plants of different species.

Let the quantity of particles these burners take never be so great, the following crops would not miss them or suffer any damage by the want or loss of them were they not the same particles which would have nourished those crops had the burners left them behind, "quiet and undisturbed." Neither could weeds be of any prejudice to corn if they did draw off those particles only that suit the bodies of weeds, the rest lying all quiet and undisturbed the while. But constant experience shows that all sorts of weeds, more or less, diminish the crop of corn.

If these things were as the Doctor affirms, why do farmers lose a year's rent at the charge of fallowing and manuring their land after so few crops, since there are many more sorts of grain as different from these and one another as those are which usually are sown?

They still find that the first crops are best, and the longer they continue sowing, the worse the last crops will prove, be they never so different a species, unless the land were not in as good tilth for the first as for the subsequent, or unless the last were a more robust species.

This matter might be easily cleared, could we perfectly know the nature of those supposed unsuitable particles, but in truth, there is no more to be know of them except that they are carried away b the atmosphere to a distance, according to the velocity of the air, even miles off and never are likely to return to the spot of ground from whence the plant raised them.

But we must not conclude that these particles, which pass through a plant (being a vastly greater quantity than those that abide in it for its augmentation) are all unsuitable. For since the life of animals depends upon that of plants, it is not unreasonable to imagine that nature may have provided a considerable overplus for maintaining the life of individual plants, when she has provided such an innumerable overplus for continuing every species of animals.

But suppose that these cast-off particles were, when taken in, unfit for the nourishment of any manner of vegetables. Then the Doctor must fancy that the wheat has a very scrupulous conscience to feed on these particles, which were neither fit for its own nourishment nor of any other plant, and at the same time to forbear to take the food of barley, peas, and oats, letting that "lie still and undisturbed all the while," as he says it does. He gives no reason to believe this.

He says that the great part of the terrestrial matter, mixed with the water, passes up into the plant along with it, which it could not do if only the peculiar matter proper to each plant passed up into it. And after he has shown how apt the vegetable matter is to attend water in all its motions, and to follow it into each of its recesses, being by no filtration or percolations wholly separable from it. It is strange he should think that each plant leaves the greatest part of it behind, separated from the water which the plant imbibes.

There are, doubtless, more than a million sorts of plants, all of which would have taken up the water, and had each as much right to its share (or "proper matter" in it, as the Doctor's plants had). And then there would be but a small part of it proper to each of his plants, and these leaving all the rest behind, both of the water wherewith the glasses at first were filled when the plants were put into them and also all the additional water daily supplied into them afterwards.

So much more terrestrial matter must have been brought into these glasses in proportion to the added water, and so very small a part as could be proper to each of his plants being carried off, there must have remained in these glasses a much greater quantity of terrestrial matter at the end of the experiment than there remained in the glasses F or G (mentioned in previous chapters) which had no plants in them, nor any water added to or diminished from them. And yet, somehow quite the contrary appeared!

Had the plant consumed with the 2,501 grains of water no more than its proper share of the vegetable matter, it could not have attained thence an increase of 3.25 grains, nor even the thousandth part of one grain. But he found

"this terrestrial matter, contained in all water, to be of two kinds: the one properly a vegetable matter, but consisting of very different particles, some of which are proper for the nourishment of some kinds of plants, others for different sorts, &c."

This, indeed, would have been a most wonderful discovery, and might have given us a great light if he had only thought to tell us in what language and character these proper differences were stamped or written upon the vegetable particles. How could he tell the difference between those which were proper or the nourishment of some kinds of plants, and for other sorts when the particles themselves, he says, were scarcely visible? Certainly it must be a great art to decipher the language of plants from invisible characters.

Doctor Woodward seems to have had as good eyes and as strong an imagination as the old woman who saw the needle upon the barn but could not see the barn.

While I will by no means call in question the veracity of so learned and good a man, and therefore am willing to believe he made this extraordinary observation in his sleep, I am yet reproached by Equivocus for insulting the ashes of this gentleman. But in truth he was living when I wrote this Chapter; even if he was not, I am sure I believed so and I hope what I have written can no way reflect upon the Doctor's memory. Yet as he was a man, and liable to be deceived by too great a zeal for a favorite hypothesis (which sometimes makes one imagine one sees a thing that has no real existence).

This observation of the Doctor's, as he expresses it, seeming to have been made by inspection upon a glass of water with earth in it, for the discovery of all the different sorts of particles in that earth; if I had contradicted the result of his observation concerning the "vegetable matter, consisting of very different particles, some of which (the Doctor says) are proper for the nourishment of some kinds of plants, others for different sorts, &c.;" as to the fact related from a clear ocular inspection, it might have reflected more on the Doctor's ingenuity, than to impute it, as I have, to the effect of mere imagination, seduced by a zeal for his hypothesis.

However, at the worst, I presume the refuting and exposing an error so injurious to mankind, may atone for an expression or two in my arguments thereupon which are not injurious to the probity or veracity of him who advanced that error, but that are rather an excuse for his mistake. And if Equivocus speaks true, when he says that Columella's first Essay was written to ridicule an error of his contemporaries, why should not an error so fundamental as this be ridiculed now, since its being shown to be ridiculous is an argument that weighs more with many husbandmen than any demonstration? And I think that no argument consistent with truth should be omitted which can any way conduce to the establishing a principle that is essential towards treating of agriculture as a science.

Notwithstanding examination, this dream will deceive none except those who are very fond of old errors. Yet even for them there is an experiment which may convince them:

At the proper season, tap a birch-tree in the body or the boughs, and you may have thence a large quantity of clear liquor, very little altered from water, and you may see that every other species of plants that will grow in water, will receive this, live, and grow in it, as well as common water. You may make a like experiment by tapping other trees, or by water distilled from vegetables, and

you will find no other species of plants into which this water will not enter, and pass through it, and nourish it too, unless it be such a species as requires more heat than water admits (or unless the peculiar vessels of that it has first passed through have so altered the vegetable particles contained in that water that it comes to act as poison upon some other particular species).

The Doctor concludes,

"*that water is only the agent that conveys the vegetable matter to the bodies of plants, that introduces and distributes it to their several parts for their nourishment. The matter is sluggish and inactive, and would lie eternally confined to its beds of earth, without ever advancing up into plants, did not water, or some like instrument, fetch it forth, and carry it unto them.*"

I think that the Doctor has made quite evident that water is very capable in the office of a carrier to plants. But as to the office of such an agent as his hypothesis bestows upon it? The thing seems impossible for water to execute. For it cannot be imagined that water, being itself but mere homogenous matter, itself without the gift of any life or sense, should distinguish each particle of vegetable matter, proper and peculiar to every different species of plants (which are innumerable) and when it is to act for the wheat, to find out all the particles proper to that sort of grain, to rouse only those particular sluggards from their beds of earth, letting all the rest lie quiet and undisturbed the while. It seems ridiculous, but this is what the Doctor claims, when it is seen that wheat cannot choose what it consumes.

And it is ridiculous to suppose that this agent frees the wheat particles from their confinement, and conveys, introduces, and distributes them, and only them, into the several parts of the wheat!

Certainly no mortal, except Doctor Woodward, can pretend to distinguish the particles of vegetable matter by any characters, hieroglyphics, or other manner whatsoever, so as to determine to what species, or class of plants, they are severally proper and peculiar; neither is it probable, that any botanist is acquainted with half the distinct species of vegetables. Yet, according to the Doctor, all the vegetable particles and all the species of vegetables must be perfectly and distinctly known by water before it be capable of performing such a nice task of an agent.

Or else, when wheat, barley, and oats, are all growing together, in the same foot of ground, with their roots so entangled together, that no man can possibly distinguish the one from the other by viewing the roots, how should this insensible agent be punctual in delivering to each its own proper particles?

Imagine, for a moment if water, which must most exactly execute a commission of disturbing these three sorts of particles should err when it had fetched them forth. If it should err in the delivery of them, and carry the wheat-particles to the barley, and those of barley to the oats, it would be a mistake of worse consequence, according to the Doctor's opinion, than that of the recent London undertaker's, who being charged to inter an old man in Northumberland, and a young lady in Cornwall, carried the man to Cornwall, and the lady to Northumberland (her mother, for mitigation of grief, would not be satisfied without a last sight of her daughter's corpse; but, when the coffin was opened, the error was discovered by the indubitable criterion of an old shriveled face, with a huge grey beard).

While it is no real injury to a person deceased if the place of his burial be mistaken if water should mistake thus in the taking up, carrying, and delivery of vegetable particles, all plants would be (upon the Doctor's hypothesis) starved or poisoned, and animals could not long survive all plants.

But do not fear such a disaster. Since all the different species of plants continue to live, their life proves that the vegetable particles of earth are not proper to one or the other, but common to them all for their nourishment if these particles are taken up, carried, and introduced into the vegetable vessels by water. And water need not be capable of distinguishing either different vegetable particles, nor different vegetables.

Since it is unreasonable to believe that water can have such extraordinary skill in botany, or in micrography, as to be qualified for a sufficient agent in such an abstruse matter, I conceive water to be only an instrument or vehicle, which takes up indifferently any particles it meets with (and is able to carry) and advances them (or the food they yield) up into the first plant whose roots it comes in contact with, and that every plant it meets with, does accept the food it is offered without distinguishing any different sorts or properties in them until they be so far introduced and advanced up into the vegetable vessels that it would be in vain to distinguish them. Whatever the terrestrial matter plants imbibe with the water will kill or nourish them as it appears by its effects, but which cannot be foreknown or prevented without the help of faculties that plants are not endowed with.

Mr. Bradley seems to have carried this error further than any author ever did before. Yet he carries it poorly, supporting it by affirmations only or by such arguments (I cannot say reasons, for no reason can be against any truth) as go near to confute the very opinion he pretends to advance by them.

He ascribes to vegetables the sense of taste, [303] by which, he thinks, they take such nourishment as is most agreeable to their respective natures, refusing the rest and will rather starve than eat what is disagreeable to their palate.

In the Preface to his Vol. I. page 10, of his Husbandry and Gardening, he says, "they feed as differently as horses do from dogs, or dogs from fish."

But what does he mean by this instance, Vol. I. page 39, "that thyme, and other aromatics, being planted near an apricot-tree, would destroy that tree, helps to confirm, that every plant does not draw exactly the same share of nourishment?"

I believe there is no need for him to give more instances to disprove his assertion than this one. His conclusion, "the earth afforded to the thyme and apricot-tree had been divided into two shares, both could not have had them."

But this his instance proves, that those aromatics robbed the apricot-tree of so much of its share as to starve it; and that they, though of so very different a nature, drew from the earth the same nourishment which the apricot should have taken for its support, had not the aromatics been too hard for it, in drawing it off for their own maintenance.

He believes that all the juices of the aromatics were as poison to the apricot and that, according to my experiment of the mints some of their roots might discharge some kind of moisture in dry weather given them by others that had it for their own use, and that the apricot roots mingling with them might imbibe enough of that liquor, altered sufficiently by their vessels, to poison and kill the tree.

Some of the Anticircularians (but Mr. Bradley was not one) may believe, that the chyle is altered and made into sap in the roots... but the experiment of my mint G will show that no such alteration is made in the roots.

[303] Though plants can taste, they cannot do much about it: see the experiments of Darwin and Darwin, discussed previously. –A.B. & M.C.

But then, where was the tree's distinguishing palate? Why did it not refuse this juice, which was so disagreeable as to kill it? And as to his notion of vegetables having palates, let us see how it agrees with what he affirms:

"That it is the vessels of plants that make, by their filtrations, percolations, &c., all the different tastes and flavours of the matter, which is the aliment of plants; and that before it be by them so filtered, &c., it is only a fund of insipid substance, capable of being altered by such vessels into any form, colour, or flavour."

And Vol. I. p. 38:

"the different strainers, or vessels of the several plants, growing upon the spot of earth, thus impregnated with salts, alter those salts or juices, according to the several figures or dimensions of their strainers; so that one plant varies, in taste and smell, from others, though all draw their nourishment from the same stock lodged in the earth."

See Mr. Bradley's Palates of Plants, and the insipid substance he gives them to distinguish the taste of, how they agree?

They must, it seems, within their own bodies, give the flavour to this insipid substance, before their palates can be of any use; and even then, it is impossible to be of any use, but in the manner of the dog returning to his vomit.

They would have as much occasion for the sense of smelling[304], as of taste, but after all, of what use could either of the two be to plants without local motion of their roots (which they are so destitute of) that no mouth of a root can ever remove itself from the very point where it was first formed? A root has all its longitudinal increase at the very end, should the spaces between the branchings increase in length, those branches would be broken off and left behind, or else drawn out of their cavities, and this would destroy the plant.

All the branches, except the foremost, would be found with their extremities pointing towards the stem, the contrary of which posture they are seen to have! And if they moved backwards? That would have much the same effect on all the collateral branching as to destroy them. Smell and taste then could be of no manner of use to vegetables [for the consumption of food – A.B. & M.C.], if they had them; they would have no remedy or possibility to mend themselves from the same mouths, removing to search out other food, in case they had power to dislike what was offered them.

Plants cannot give neither can plants receive, require, or make use of any variety from their diet of soil, as animals do from their diet[305]. It would be lost upon them and nature would have acted in vain to give smell and taste to vegetables, or to give them a charming variety of relish and savor in their food without giving them senses necessary to perceive or enjoy them. It would be like light and

[304] Some plants do communicate by chemicals released in the air and ground to coordinate the sexes of their species, warn members of their species of predators (allowing their friends to produce toxins for their defense), and other critical data. –A.B. & M.C.

[305] Some plants do put herbicides they are immune to into the soil to kill (or weaken) their neighbors, others release fungicides, anti-microbials or sometimes release agents to promote fungus, microbes or other plants. But these effects are so minimal that they were only recently discovered, and at Universities across the nation, researchers are engaged are trying to breed plants with the ability to produce useful quantities of these agents. –A.B. & M.C.

colors to the blind, sound and music to the deaf; or like giving eyes and ears to animals, without light or sound to affect them.

The mouth of plants, situate in the convex superficies of roots, are analogous to the lacteals, or mouths, in the concave superficies of the intestines of animals. These spongy superficies of animal guts, and vegetable roots, have no more taste or power of refusing whatever comes in contact with them, the one than the other.

The free open air would be equally injurious to both: and if exposed to it, it would dry and close up the fine orifices in guts and roots; therefore nature has guarded both from it. Nature has also provided for the preservation of both vegetables and animals (I do not say equally) in respect of their food, which might poison them, or might not be fit to nourish them.

The security of plants (the best that can be) is their food itself, soil; which having been altered by no vessels, is always safe and nourishing to them: for a plant is never known to be poisoned by its own natural soil, nor starved, if it there were enough of it with the requisite quantities of heat and moisture.

Roots being therefore the guts of plants, have no need to be guarded by senses; and all the parts and passages, which serve to distinguish and prepare the food of animals, before it reached the guts, are omitted in plants, and not at all necessary for them.

The food of most animals is also soil, but it is very variously changed and modified by vegetable or animal vessels (or by both) so that some of it is made wholesome and others poisonous, so that if this doubtful food should be committed to the intestines, without examination, as the pure unaltered earth is to roots, there would, in all probability, be very few animals living in the world, except there be any that feed on earth at first hand only, as plants do.

Therefore nature has endowed animals with smell and taste to act as sentinels, without whose scrutiny these various uncertain ingredients are not admitted to come where they can enter the lacteals, and to distinguish, at a sufficient distance, what is wholesome and friendly, from what is hurtful: for when it is once passed out of the stomach into the guts, it is too late to have benefit from emetics; its venom must then be imbibed by the lacteal mouths, and mix with the blood, as that must mix with the sap, which comes in contact with the lacteals in the superficies of roots (nature having left this unguarded).

The nutriment, or chyle, that a root takes in, must mix with the sap in the leaves, unless some of it happens to pass out at other roots in the manner described in my note upon Circulation.

Yet, plants seem to be better secured by the simplicity of their food than animals are by their senses. To compensate that inequality of danger, animals have pleasure from their senses, except some miserable animals (and such they are) that have more pain than pleasure from them. But I suppose more animals than plants are poisoned and that a poisonous animal is less fatal to a plant than a poisonous plant is to an animal.

An instance of this—I have been told, by very credible persons, that a man walking in a garden, gathered a sprig of sage, and ate it, which soon brought upon him the symptoms of poison and death. They dug up the root of sage, and found a toad under it. Some of the effluvia of this loathsome animal had passed the vessels of that wholesome plant, without any apparent injury to it, though all its strainers were not able to correct the venom.[306]

[306] It is unlikely that the toad would have killed the person, even had the person eaten the toad directly. It is more likely something else killed the person, whether they ate a poisonous plant by mistake, ate spoiled food, or some poison had in another way entered the sage. –A.B. & M.C.

Here I remark that the mint E suffered more pestiferous effects from the garlic, of its own genus, than the sage did from the toad, though of a different genus.

It killed the man, but was not strong enough to kill the sage. This shows that plants have not occasion of palates, as animals have.

I say no more of Mr. Bradley's vegetable palates; I proceed to some other arguments against the necessity of changing sorts of vegetables, on account of their taking different nourishment.

It being sufficiently proved, that every sort of vegetable, growing in the same soil, takes, and is nourished by the same sort of food, it follows from hence, that the beneficial change of sorts of seeds or plants, we see in the common husbandry, is not from the quality of the sorts of food, but from other causes; such as,

I. Quantity of the food
II. Constitution of the plants
III. Quantity of the tillage

Dr. Woodward's case upon this hypothesis is interesting. He sowed three proportions of barley, oats, and peas all together in the same acre of ground in the same year, and found they make three as good crops as if sown singly in three successive years, and two crops of wheat in one year likewise. But every farmer can tell that these three proportions of seed would not yield half the crop together, as one would do single; and would scarce produce more than to show what grains were sown, and which of the sorts were the strongest, and the most able robber. [307]

Though this failure would, in truth, be from no other cause than want of the sufficient quantity of food which those three crops required, the Doctor thinks that all three crops might succeed together very well, taking each its proper nourishment, were it not for want of room, air, and sun.

I have been credibly informed, that on one perch of ground there has grown a bushel of corn, which is twenty quarters to an acre. Mr. Houghton relates twenty-six, and even thirty quarters of wheat on one acre. There has certainly grown twelve quarters of barley to an acre, throughout a whole field; therefore, unless a crop exceed the least of these, or, indeed, the greatest of them (if the relation be true) a crop cannot fail for want of room; for one acre (be it of what nature it will, as to the soil of it) must have as much room for a crop to grow on, as any other acre.

[307] We repeated this experiment and found the opposite. We were able to sow even twenty kinds of seeds in the same bed, provided ample tillage and water was provided. Though some of our customers protested, the practice being contrary to their Bible, it proved to be more profitable. Also, in Colorado there is a variety of climate in a single season, and if the year proved to be hot or cold, dry or moist beyond average, we were assured some of the crop would thrive, even if others struggled. To verify this, we sowed a control bed nearby of just one kind of seed, and observed that there was no difference between the monoculture and polyculture. We obtained (largely) satisfactory results in a separate trial when we allowed weeds to grow among the plants in the beds, treating them like some domesticated crop. Several weeds crowded out our domestic crops, but these proved their worth by providing habitat to defending friendly animals, bringing up water to our crops from the deep, and shading them against the hot sun – we found, usually, no impact from weeds when we practiced good tillage, even when no additional water was applied. But, we would have preferred a more saleable crop over the weeds, and are content to allow them to remain in reservations. –A.B. & M.C.

Then there was room for Dr. Woodward's three crops together, to produce as much as three common crops do. Yet all these together will scarce yield one quarter of corn, though there is room at least for twelve.

The same air and sun that had room to do their office to Mr. Houghton's acre, why should they not have room to do the same to Dr. Woodward's acre, when the three crops growing on it at once, though pretty good ones, might require less room than Mr. Houghton's crop did?

I perceive that those authors, who explain vegetation, by saying the earth imbibes certain qualities from the air, and by specific qualities, and the like, also lay a great stress upon the perpendicular growth of vegetables, seeming to imagine there is little else necessary to a good crop but room.

Mr. Bradley, in his arguments concerning the value of a hill, does implicitly say as much.

But if they would only consider the diameters of the stems with the measure of the surface of an acre, they would be convinced that many, even of Mr. Houghton's crops, might stand in a perpendicular posture upon an acre and have room be left over.

One true cause of a crop's failing is want of a quantity of food to maintain the quantity of vegetables which the food should nourish. When the quantity of food which is sufficient for another species (that requires less) but not for that which last grew, to grow again the next year, then that other is beneficial to be planted next to it.

The second true cause is from the constitution of the plants; some require more food than others, and some are of a stronger make, and better able to penetrate the earth, and forage for themselves. Therefore oats may succeed a crop of wheat on strong land, with one plowing when barley will not because barley is not so well able to penetrate as oats, or beans, or peas are. [308]

So a pear-tree may succeed a plum-tree when another plum-tree cannot because a pear is a much stronger tree, and grows to a much greater bulk, so inclined to be a giant that it is hard to make it a dwarf and will penetrate and force its way through the untilled earth, where the other cannot, being of a weaker and less robust constitution, not so well able to shift for itself. [309]

The pear could penetrate pores that the other could not. Mr. Evelyn says, in his Discourse of Forest-Trees, "that a pear will strike root through the roughest and the most impenetrable rocks and clefts of stone itself." He says likewise, in his Pomona, "that pears will thrive where neither apple or other fruit could, in appearance, be expected."

I can scarce think that a larger plant takes in larger particles than a small one for its nourishment; if it did, I cannot believe, that he thyme could have starved the apricot-tree; it must have left the larger particles of food for that tree, which probably would have sufficed to keep it alive; I rather think that great and small plants are sustained by the same minute particles; for as the fine particles of oats will nourish an ox, so they will nourish a tomtit, or a mite.

Some plants are of a hotter constitution and have a quicker digestion, like cormorants or pigeons devouring more greedily, and require a greater quantity of food than those of a colder temperature of equal bulk, whose sap having a more languid motion in proportion to the less degree

[308] Tull is partially correct. Oats, peas and beans encourage nitrogen fixing bacteria, increasing the quantity and quality of food in the soil. Wheat does not. It is not a matter of "reaching," but of symbiotic advantage. –A.B. & M.C.

[309] Again, this is partially true. Other factors involved are microorganisms, which, feeding upon the dead plum, would infect the live plum succeeding it. However, these microorganisms can be inhibited through the competition of a well tilled soil, polycultures and, sometimes, a fallow. – A.B. & M.C.

of heat in it, sends off fewer recrements (therefore a less supply of food is required in their room). This may make some difference in the one succeeding the other; because the hot-constitutioned leaves not enough for its own species to succeed again, but leaves enough for a species of a colder constitution to succeed it. [310]

But the third and chief cause of the benefit of changing sorts is the quantity of tillage in proportion to which the food will be produced.

The true cause of why wheat is not (especially on any strong soil) to be sown immediately after wheat, is, that the first wheat, having stood almost a year on the ground has grown hard, and wheat seed-time being so soon after harvest in England, there is not space of time to till the land so much as a second crop of wheat requires.

Sometimes, in poorer land that is lighter, wheat has succeeded wheat with tolerable success. But I have seen, on very rich strong land, the first crop lost by being much too big, and one following it immediately, quite lost by the poorness of it, and not worth cutting.

This was enough to satisfy me that the tillage, which was so much easier performed in less time, sufficed for the light land, but not for the strong and if the strong land could have been brought into as good tilth as the light (like as in the new husbandry it may), it would have produced a much better second crop than the light land did.

From all that has been said, these may be laid down as the maxims: that the same quantity of tillage will produce the same quantity of food in the same land and that the same quantity of food will maintain the same quantity of vegetables.

Add *ceteris paribus*; for when the land has been more exhausted, more tillage (or dung) or rest will be required to produce the same quantity of food, than when the land hath been less exhausted. By tillage is here meant, not only the number of plowings, but the degree of division or pulverization of the soil; or if perchance the soil is extraordinarily much exhausted by many crops without proper tillage between them, the greater degree of pulverization, by plowing or dung (which is only a succedaneum of tillage), and also a longer time of exposure may be necessary to counterpoise that extraordinary exhaustion.

It is seen, that the same sort of weeds which once come naturally to a soil, if suffered to grow, will always prosper in proportion to the tillage and manure bestowed upon it without any change (and so are all manner of plants that have been yet tried by the new husbandry, seen to do).

A vineyard, if not tilled, will soon decay – even in rich ground – as may be seen by those in France, lying intermingled as our lands do in common fields. Those lands of vines, which by reason of some law-suit depending about the property of them, or otherwise, lie a year or two untilled, produce no grapes, send out no shoots hardly; the leaves look yellow, and seem dead, in comparison of those on each side of them, which, being tilled, are full of fruit, send out a hundred times more wood, and their leaves are large and flourishing; and continue the same annually for ages, if the plough or hoe do not neglect them.

No change of sorts is needful in them, if the same annual quantity of tillage (which appears to provide the same annual quantity of food) is continued to the vines.

But what in the vineyards proves this thesis most fully, is, that where they constantly till the low vines with the plow, which is almost the same with the hoe-plow, the stems are planted about

[310] Some plants native to hot countries have developed elaborate ways of conserving water, such as closing pores in the daytime heat, developing waxes or self-shading growth. Plants adapted to cold insulate themselves and have sap which is less apt to freeze. –A.B. & M.C.

four feet asunder, checker-wise; so that they plow them four ways. When any of these plants happen to die, new ones are immediately planted in their room, and exactly in the points or angles where the others have rotted; for, if planted out of those angles, they would stand in the way of the plough. These young vines, I say, so planted in the very graves, as it were, of their predecessors, grow, thrive, and prosper well, the soil being thus constantly tilled; and if a plum-tree, or any other plant had such tillage, it might as well succeed one of its own species, as those vines do.

It is observed, that white-thorns will not prosper, set in the gaps of a white-thorn hedge; but I have seen the banks of such gaps dug, and thrown down one summer, and made up again, and white-thorns there replanted the following winter, with good success.

But note, that the annual plowing of the vines is more beneficial than the one summer tillage of the banks, the vines having it repeated to them yearly.

I have, by experience and observation, found it to be a rule, that long, tap-rooted plants, such as clover and sanfoin, will not succeed immediately after those of their own or any other species of long tap-roots, so well as after horizontal-rooted plants; but, on the contrary, horizontal will succeed those tap-roots as well or better than they will succeed horizontal.

I confess, this observation did, for a great while, cheat me into the common belief, that different species of plants feed on different food; till I was delivered from that error, by taking notice, that those tap-roots would thrive exceedingly well after turnips, which have also pretty long tap-roots, though turnips never thrive well immediately after clover or sanfoin. Thus I found the true cause of this exception to that rule, to be chiefly the different tillage .

But when clover has been fed by cattle, and the ground being good and well tilled, turnips may thrive immediately after clover; therefore this is an exception to the general rule.

Land must be well tilled for turnips, which also are commonly hoed. They stand scarce ever above nine months of a year, and are then fed on the ground, and then the succeeding crop of corn has, by that means, the benefit of twice as much tillage from the hoe as otherwise would be given to it. And the broad clover or sanfoin, sown with the corn (if the corn be not so big as to kill it), will enjoy, in its turn, a proportion of the extraordinary tillage and of the dung of cattle which feed the turnips, and thrive accordingly; but broad clover and sanfoin, being perennial plants, stand on the ground so long that it lies several years untilled so that turnips sown immediately after these do fail for want of the due tillage for which there is not sufficient time. Plowing by the common plows requires two or three years to make it fine enough for turnips, or for a repetition of clover or Sanfoin in strong or swerdy land.

Another reason why any crop succeeds well after turnips (and besides their being spent on the ground where they grow), is their cold constitution, by which they are maintained with less food than another plant of the same bulk.

The parenchyma, or fleshy part of a turnip, consists of a watery substance that cools the vessels. This slows the sap's motion in proportion to the very low degree of heat it has, and thus it sends off its recrements in the same proportion likewise, requiring less of the soil's nourishment to supply those recrements.

A turnip has larger chyle-vessels in proportion to its sap-vessels than many other sorts of plants have, and the greatest part of this chyle being water, it may well be supposed colder than sap.

This is seen when a bushel of turnips, mixed with a quantity of wheat flour, is made into bread and well baked: this bushel of turnips gives but few ounces increase in weight, more than the same quantity of wheaten flour made into bread and baked without any turnips. This shows there is in a turnip very little earth (which is the most permanent substance of a plant), and the oven discharges in vapor near all but the largest vessels. Its earthy substance being so small is a proof it is

maintained by a small quantity of earth and upon that account, also of less damage to the next crop than another plant would be, which required more of the solid nourishment to constitute its firmer body (such as a charlock). When a charlock comes up contiguous to and, at the same time with, a turnip, it does so rob the turnip that it attains not to be of the weight of five ounces, when a single turnip, having no more scope of ground, and, in all respects (but the vicinity of the charlock) equal, weighs five pounds. Yet that charlock does not weigh one pound! And where three turnips are coming up and growing contiguous, they will weigh four pounds, a charlock joined with two or three turnips will all together will be less than one pound, upon no less space of ground.

This observation cannot be made except where turnips are drilled in rows and there it is easy to demonstrate, that a charlock, during the time of its short life, draws much more earth than a turnip of equal bulk, from an equal quantity of ground. [311]

The true cause why clover and Sanfoin do not succeed so well after their own respective species, or that of each other, as corn, etc. can, is, that they take great part of their nourishment from below the plow's reach, so as that under-earth cannot be tilled deep enough, but the upper part may be tilled deep enough for the horizontal roots of corn, etc., towards which the rotting of the clover and Sanfoin roots, when cut off by the plow, do not a little contribute.

And there is doubt but that, if the under-earth could be as well tilled for the tap-roots, as the upper-earth is for the horizontal, the tap-roots would succeed one another as well as the horizontal would succeed them, or those of their own species, or, as the tap-roots do the horizontal.

That the rotting of vegetable roots in the ground does ferment therein, and improve it for horizontal-rooted plants, I am convinced by an accident: my man had ploughed off the earth close to the rows in a field of extraordinary large turnips designed for seed. This earth was neglected to be thrown back to the rows until a severe frost in the winter came and killed the turnips, upon which, in the spring the field was sown with barley upon the level with only once plowing, and that crosswise of the rows. The turnips had stood so wide asunder, that the spot whereon each had rotted appeared like the spot whereon a horse had urinated in tilled ground, and was of a deeper color and much higher than the barley that grew round those spots, and yet none of it was poor. As the roots of clover and sanfoin are very much less, yet the greater number rotting in ploughed ground must be of great use to a following crop of corn. [312]

I will here relate two examples of this in sanfoin; the one is, that a field of twenty-five acres drilled with sanfoin except three acres in the middle of it, which was at the same time sown with hop-clover; after eight years the whole field was ploughed up by a tenant, and sown with corn: the sanfoin had been mowed yearly as the hop-clover was not mowed at all, but fed by horses tethered (or staked) thereon the first and second years, and after that had nothing on it but poor natural grass.

[311] Our trials with the multiple plants in the beds examined the cost of weeding out those predatory plants and, though dependent on the current price of labor, successfully reduced the cost of weeding more than the sometimes reduced yield in hand weeding. Some farmers have attempted to reduce weeding costs by mechanically hoeing between rows in a bed. Certainly, it is more harmful to the environment to remove the weeds and therefore more costly in the long-term, reserves of native plants service the area as well as localized weeds. –A.B. & M.C.

[312] Fukuoka would sometimes bury logs just for this purpose. We have tilled in leaves from trees with greatest result and greatest profit, but lawn clippings, chipped wood, chopped wood, logs and other organic matter works beautifully as well. –A.B. & M.C.

The whole field was managed alike when ploughed up; but the three acres produce visibly worse crops of corn than the rest all around it, which had produced sanfoin.

The other example, or instance, was, where an acre, part of a field, was, by a fancy, drilled with sanfoin in single rows about 33 inches asunder, but was never hoed: after seven years it was ploughed up with the rest of the field across the rows, and sown with oats upon the back of three months after plowing. These rows were as visible in the oats as if the sanfoin had still remaining there. The oats in the rows where sanfoin had been, looked of a deep green flourishing color at first coming up, and until they were about half a foot high, and the spaces between them looked yellowish. But afterwards the difference of their color disappeared, all the crop being very good. Upon this I imputed it to the rotting of the roots, which by their singleness were very large; and when the different colors disappeared, I suppose the roots of all the oats had reached to the benefit of the rotted roots, which might also be then spread further into the spaces, and I doubt not but that the rotting of broad clover-roots has the same effect as of Sanfoin, for manuring of land, especially when the roots are large. [313]

The under-earth, in some time, is replenished by what the rains leave when they sink through it and then tap-rooted plants may be there nourished again even while the upper-earth is drained by the corn. And so no change is so beneficial as that between tap-rooted plants and those which have only horizontal ones. The former are provided for by rains, though not so speedily as the later are by tillage and hoeing.

Pasture requires no change of herbs; because they have annually the same supply of food from the dunging of cattle that feed on them, and from the benefit of the atmosphere.

Meadows hold out without change of species of grass, though a crop be carried off every year. The richness of that soil with the help of the atmosphere, dung of cattle in feeding the after-crop, or else flooding from the overflowing of some river, some, or all of which, supply the place of the plow to a meadow.

Woods also hold out beyond memory of tradition, without changing sorts of trees; and this by the leaves, and, perhaps, old wood rotting on the soil annually, which operate as a manure, because, as has been said, soil which has once passed any vessels, is so changed, that for a long time after it does not regain its homogeneity so much as to mix with pure soil without fermenting. And by the descent of the atmosphere, the trees shadowing the soil to prevent the renascent of what that brings down...all this resembles tillage, continually dividing the soil, and renewing the food equal to the consumption of it made by the wood. [314]

And the last argument I shall attempt to bring for confirmation of all that I have advanced is that which proves the truth and use of the rest: that when any sort of vegetable, by the due degrees of heat and moisture it requires is agreeable to a soil, it may, by the new horse-hoeing husbandry, be continued without ever changing the species.

[313] We alternate where the beds and aisles are yearly so that we can maintain food and shelter for the small and large animals that aid us in our farming. Besides, alternating annually like this improves the whole field, and our aisles are never so far from the beds that the plants can't enjoy the food produced by the microorganisms feeding on last year's crop.

It is important to note again that the plants do not eat the old plants, but the soil made by the microorganisms eating the old plants. –A.B. & M.C.

[314] In some modern lumber farms, maple syrup farm, palm and other orchards, the trees are tilled, fertilized, treated with herbicides, pesticides and especially fungicides. All these additives could be avoided through proper tillage, biodiversity and nature reservations. –A.B. & M.C.

CHAPTER SEVENTEEN: OF CHANGE OF INDIVIDUALS OR, IMPORTING SEED

In choosing to import seed rather than save last year's seed for next year's planting, the farmer is choosing plants which are adapted to different climates than that in which the farm is located: such seeds, while of the same genotype, are of a different phenotype (having the same genes, but presenting them differently) because a parent generation will effect which genes are activated and deactivated in their progeny

As the benefit of changing species of seeds is actually from a difference in the requirements of those species for tillage before planting, so the benefit of changing individuals of the same species (or the importation of seed) appears to be from those causes which are, generally, themselves the effects of different causes. Such causes are usually the climates in which the parent generation matured their seeds.[315] These include things such as heat and moisture, which may also vary very much in the same latitude and neighborhood.

Climate may differ even from one side of a mountain to another

One mountain in the country of Mogul (related by Mr. Evelyn, from Monsieur Bernier) on its south side produces Indian plants, and on the north side European plants from different exposures.

Climate sometimes varies even within a single field

And some parts of a field may retain water longer and will be colder, some parts may allow water to pass down quickly and by the nature and figure of its parts cause such a refraction and reflection of the sun's rays that give a great warmth. And in sand and gravely grounds that are well situated, some lands have an under-stratum of some sort of hollow matter under the staple, or upper-stratum, wherein the plow is exercised. This hollow matter lets the water pass down the sooner from the surface, whereby the staple of the ground becomes the drier, and consequently warmer.

[315] The farmer, in choosing to import seed rather than save some seed from their own crops, is choosing to bring in individuals adapted to a different climate than that which the farm is situated: plants modify their progeny to be more adapted to the environment of their parents through the activation and deactivation of various genes, and so these imported seeds, while of the same genotype, are of a different genetic phenotype, or present those genes in a different way. –A.B. & M.C.

Climate effects the characteristics of plants: in example, flax imported from Holland produces as fine of flax when planted in England only the year of the importation, its progeny adapts to English conditions and degenerates within 2 or 3 generations

Any beneficial change of individuals seems rather to be from the aforementioned causes than from change of food and these causes show their efficacy, chiefly in the generation of those seeds: flax-seed brought from Holland, and sown here, will bring as fine flax as there, but the very next generation it becomes coarser, and so, degenerating gradually, after 2 or 3 generations becomes no better than the common ordinary sort. Yet the plant's food is the same when the flax is fine as when it is coarse: the soil does not make the flax fine, but its breeding does.

Similar effects of climate can be observed in all species, especially wheat, silk worms, barley, etc.; the value of buying from breeder farms

And so it is when individuals of wheat are changed; so silk-worms, hatched and bred in France, of eggs or seed, brought from Italy, will make as fine silk as the Italian, but the eggs of these lain in France, and their issue, will make no better silk than the French (even though their food is from the leaves of the same mulberry-trees when they make fine silk and coarse). It is from the climate where the eggs are impregnated, not where they have their incubation or food when hatched and fed to their lives' end that this difference happens. [316]

[316] The mother and father both give to their issue genetic material. While changes to the genetic material occur slowly, changes to the way the genetic material effects the organism can even be instantaneous within the generation, without reproduction. Genes can be activated and deactivated in response to stimulus, diet, or other factors within the lifetime of the individual. Of course, offspring from the individual will be born with certain environmentally triggered traits activated or deactivated to give the next generation advantages that its parents did not have. Thus, corn bred in a drought will be more drought tolerant than well watered corn; a person who smokes tobacco will activate genes that help protect their lungs – and the lungs of their children – from smoke, usually in the form of an asthma; when a person eats meat, they must have certain genetic material activated to better process the toxic proteins. Eventually, environmental triggers can result in permanent genetic changes and the evolution of new species as has been described by Charles Darwin and others.

Darwin, himself a member of the clergy, set forth to find evidence of the great flood on the voyage of the HMS Beagle. While on his journey, he noticed that "as many more individuals of each species are born than can possibly survive; and as, consequently, there is a frequently recurring struggle for existence, it follows that any being, if it vary however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, will have a better chance of surviving, and thus be naturally selected. From the strong principle of inheritance, any selected variety will tend to propagate its new and modified form."

Farmers can use breeding to advantage by either selecting for various traits, or by pressuring genetic activation or deactivation. This is very commonly done in chickens (which have thousands of varieties, each one suited for a particular environment of production) and plants, and, to a lesser extent, in other animals and fungi.

Common barley sown once in the burning sand at Patney in Wiltshire, will, for many years after, if sown on different warm ground, be ripe two or three weeks sooner than any other which has never been impregnated at Patney. But if sown a degree further north on cold, clayey land, will, in two or three years, lose this quality and become as late ripening as any other.[317]

Barley is far from being improved by becoming rath[318]-ripe; for it loses more good qualities than it gets by being sown at Patney; it is so tender that if it be sown early the frost is apt to kill it; or if it be sown late in May on the same day, and in the same soil with the same sort of barley that is not rath-ripe, it will be much thinner bodied than the late ripe; and besides, if it happens to have any check by cold or drought, it never recovers it as the other does at what time so ever it is sown. It is now, as I am informed, gone out of fashion and very few farmers have sown it of late years. I know a little parish that I believe formerly lost about 200 Pounds per year by sowing rath-ripe barley; but long and dear experience hath now convinced them of their error, and obliged them totally to disuse it.

Even still, Patney is far from improving the species of barley, except we think it improved by becoming more weak and tender, and shorter lived; which last-mentioned quality fits it for such countries where the summers are too short for other barley to ripen.

An example of farmers selecting for various traits is the red grapefruit, which was a natural mutant discovered on a Texas roadside selected by its discoverer after he tasted the fruit and decided it was an improvement over the pink grapefruit. An example of farmers pressuring genetic changes is found in the development of the red grapefruit through radiation to pressure beneficial mutations, or in Indian Corn, which has been pressured through environmental stress to become so altered from its natural state that it became a new species.

Creatures now can also be genetically engineered. Strawberries have had genetic material from fish spliced into their DNA so that they would not freeze in the winter, and grains have been made to produce antibiotics that kill insects. While the latter resulted in partial ecological collapse after bees and butterflies began to die from the antibiotics, the former resulted in a better strawberry harvest and little or no environmental effects. The environmental implication of breeding and genetic engineering lies in the forethought of the farmer undertaking the venture. –A.B. & M.C.

[317] Professional seed and animal breeders offer all kinds of breeds to suit your needs and climates. The professional breeder also offers guarantees to germination rates, disease free seeds or babies, and will, sometimes, offer exclusivity arrangements for large buyers. While breeding your own creatures is a worthwhile undertaking, professionals are now so good at it that it is a hard decision whether to outsource breeding operations. The expense of raising crops or animals just for seed or offspring will, these days, exceed the cost of simply buying good seed or babies from a breeder. –A.B. & M.C.

[318] Rath is a kind of enclosure, in this context meaning garden. –A.B. & M.C.

Seeds and grains are to plants like eggs are to birds, and some disease can be transmitted between mother and seed or grain

The grains, or seeds of vegetables, are their eggs, and the individual plants immediately proceeding from them have not only the virtues they received in embryo (or rather in plantulis)[319], but the diseases also; for when smutty wheat is sown, unless the year prove very favorable, the crop will be smutty.

The smutty grains will not grow, for they turn to a black powder; but when some of these are in a crop, then, to be sure, many of the rest are infected and the disease will show itself in the next generation, or descent of it if the year wherein it is planted prove a wet one.

Weeds require no change of individuals

Weeds, and their seed, in the fields where they grow naturally for time immemorial come to as great perfection as ever, without change of soil. [320]

[319] Now, some seeds are again referred to as embryos, but only those which are formed within the seed and can rightfully be called "embryonic" (such as beans, peanuts and the like). –A.B. & M.C.

[320] This is not quite true, as seeds of weeds migrate with each season's maturity. The stock of a ground is thus improved and changed regularly. Even among dandelions, there are those with broader leaves and those with thinner, some with redder some with greener, some with longer and some with shorter. Only when the dandelion is brought under cultivation for the production of its leaves does this variability become important enough to require human selection.

Also, some weed seeds will last thousands of years in the soil and though they are not newcomers per se, when they sprout up out of some long-gone era, it is like a change of individuals: if not seen for many years, they are like-new. The recent passion gardeners have with old varieties of tomatoes are reintroducing new individuals not seen for hundreds of years.

There is a reason that nature changes individuals: ecological succession naturally takes place through the change of individuals and the change of species. As the ecology changes, some species and individuals are more adapted to the climate than others.

As discussed previously, an excellent example lies in bindweed. As it grows on the hot, sandy ground, it shades the soil and allows moisture to be retained. Eventually, whether the seed was there or dropped by wind or animals, a taller plant grows up – such as grasses, lambsquarters, chokecherries or bushes. The bindweed tries to pull down this newcomer, but fails. The bindweed is then shaded out as the newcomer welcomes its friends the trees. Eventually, from the bindweed grows a forest, and the bindweed seeds remain in the soil until a fire or some other disaster clears the trees and the bindweed can thrive again. The bindweed is no more or less a climax species than the trees, but serves an important role in Gaian self-regulation of the biosphere as a "pioneer" species, or a species that prepares the ground for others to thrive and dies in the process.

Gaian self-regulation results in the maintenance of an environment suited for life: a steady temperature against increasing solar radiation, asteroid impacts, geological phenomena and other threats to life. It results in a stable climate suitable for the development of civilized species, culture, language and history, the ability for species to reflect upon the soil from which their food grows and upon the stars to which their souls are inclined.

These weeds, with acorns, and other masts, crabs, sloes, hips, and haws, are thought to have been, originally, the only natural product of our climate. Therefore, other plants being exotics, many of them, as to their individuals, require culture and change of soil, without which they are liable, more or less to degenerate.

Equivocus is wrong to presume that one species can degenerate into another: wheat does not degenerate into rye and barley does not generate into bigg any more than a horse degenerates into a bull!

Equivocus, like his lower class of readers which he describes, is unable or unwilling to distinguish the difference of change of a species of plants from the change of its individuals when he pretends to bring as an argument the degenerating of the individuals of beans, etc., to prove the necessity of changing the species of them.

But to say that the soil can cause wheat to degenerate into rye, or convert rye into wheat, is what reflects upon the credit of Laurembergius: it is as easy to believe, that a horse, by feeding in a certain pasture, will degenerate into a bull, and in other pasture revert to a horse again; these are scarce of more different species than wheat and rye are: if the different soil of Wittemberg, and Thuringia, change one species, they may the other.

Equivocus, fond of everything that has no foundation of truth, asserts, "that barley will degenerate into bigg," which is a very different species. And yet he does not own from whence he stole his wonderful discovery!

Yet when things do not go to plan, sometimes more junior individuals and species must rely upon their seniors held in the reserves of the soil for countless eons or upon the wind importing their cousins from far-away lands. –A.B. & M.C.

CHAPTER EIGHTEEN:
OF RIDGES AND TERRACES

Ridges moderate heat and moisture

The method of plowing land up to ridges is a particular sort of tillage, the chief use of which is the moderation[321] it makes in the degrees of heat and moisture. Heat and moisture are two of the grand requisites of vegetation, for very different degrees of these are necessary to different species of vegetables.

Most plants require a middle degree of both heat and moisture, a method by which to learn what temperature seeds require to germinate

Those vegetables commonly sown in our fields require a middle degree of both, not being able to live on the sides of perpendicular walls in hot countries, nor under water in cold ones, neither are they amphibious, but must have a surface of earth not covered nor much soaked with water (which would deprive them of their necessary degree of heat and cause them to languish. The symptoms of such disease are a pale or yellow color in their leaves, cessation of growth, and death ensures as sure as from a dropsy).[322]

[321] Tull's word was lateration, with the connotation of changes in geographical latitude and the resulting changes in heat and moisture. –A.B. & M.C.

[322] If the ground is too hot or too cold during planting, the seeds might die after germinating. How can you tell if your seed prefers warm temperatures or cold? The question, while easily referenced by consulting any number of gardening guides, is better answered by experimentation. During the experiment, new questions and thoughts will come to mind, and a better understanding of all the factors—not just temperature—that affect seed germination will be gained. For this experiment, you will need: 100 seeds of the kind you are trying to learn about, 2 thermometers, paper towels or clean cloths (i.e. rags), ziplock or other water-tight bags (though this is not necessary, it will facilitate the experiment greatly), a refrigerator (or root cellar where the temperature will be less than room temperature, a clean (sterile) countertop and a warm indoor cabinet.

1. Select the type of seed you wish to grow. If you are unsure, select pea and squash seed.

2. Place a thermometer into the refrigerator on the shelf where the seeds will be, and one into the cabinet.

3. Moisten the seed to begin the germination process. This is best done by rinsing the seed under water at room temperature.

4. Moisten 10 paper towels. Place the towels on a clean (sterile, if possible) countertop. Place 10 seeds of each type of seed on separate towels, well spaced.

5. Place each paper towel in a ziplock bag. Put half of the bags of each type of seed into the refrigerator, the other half into the cabinet. If no ziplock or water-tight bags are available, see note attached to step 6.

Ridges can reduce water on land by facilitating run-off to rivers, or in desert lands, retard water run-off, in desert lands, ridges reduce wind erosion

The only remedy to prevent this disease in plants, is to lay such wet land up into ridges, that the water may run off into the furrows, and be conveyed by ditches or drains into some river.[323]

The more water there is in a soil, the cooler it will be

The more a soil is filled with water, the less heat it will have.

Hills with an upper stratum of soil lying upon a stratum of clay and strong lands in general will generally be at risk of having too much water; spewy hills are those on which water reaches the under layer of clay and instead of being absorbed, spreads upon it and fills the upper soil as a cistern does a fountain

The two sorts of land most liable to be over-glutted with water, are hills, whereof the upper stratum (or staple) is mould lying upon a second stratum of clay. And generally all strong deep land.[324]

6. Every day, replace the paper towel and throw away the seeds that may have become moldy. Note the temperature of the refrigerator and the cabinet. Note how the seeds swell before they germinate! If not using ziplock or water-tight bags, check several times per day to ensure that the moisture is constant.

7. After the time has elapsed that the seeds should have germinated, remove all the seeds from the bags and count how many germinated in the refrigerator, and how many germinated in the cabinet.

8. Compile the data on a table for easy reference. Align columns along two titles: the first being the average temperature of the refrigerator, the second being the average temperature of the cabinet. Three rows should be made: number of seeds germinated, number of seeds that failed, number of seeds that were thrown out because they were moldy.

Upon examining the data, it should be clear whether your seed prefers the refrigerator or the warm cabinet! If it prefers the refrigerator, it likes cool soil; if it prefers the cabinet, it likes warm soil. –A.B. & M.C.

[323] In deserts, ridges should be aligned to retard water run-off and to reduce wind erosion.

Ridges are easily made by specialized implements these days, though Tull found success in constructing them with a mouldboard plow. –A.B. & M.C.

[324] Sea and lake water will also reap havoc on agriculture, and planting crops in a tidal basin requires species adapted to it as there is very little that drainage ridges can do in those situations. Rice, both the American and Asian varieties, are suited for this, as are many of the native plants, fungi and microorganisms. Through the use of pens, various aquatic life is easily grown in such areas, including algae (a complex microorganism used for energy, vegetables, cattle feed, chemical processing and more), fish, turtles, shellfish and crustaceans. Mariculture and aquaculture are quite profitable and pleasurable, even if they produce an inferior product. Yet, as the seas continue to rise,

Hills are made wet and spewy by the rain-water which falls upon them and soaks into them as into other lands. But on a hill, the water is sometimes stopped by the clay lying next to the surface and, being unable to enter the clay, spreads itself upon it and, pressed on by more water from above, is forced to rise up into the soil lying upon it, some ways down the slope fills the upper soil as a cistern does a fountain (or jette d'eau) . The land of such a hill is not the less wet or spewy for being laid up in ridges, if they be made from the higher to the lower part of the field because the force of the water's weight will raise it so as to the cause it to issue out at the very tops of those ridges: then the earth becomes a sort of pap or batter, and becomes a quagmire. In going over it, the feet of men and cattle sink in till they come to the clay.

Alternative method of draining such a hill: French drainage (trenches filled with stones and covered with soil) must be laid across the descent of the hill and is destroyed over time by tillage

There are two methods of draining such a wet hill: the one is to dig many trenches across the hill horizontally and either fill them up with stones[323], loose or arch-wise, (through which the water, when it soaks into the trenches, may run off at one or both ends of them into some ditch which is lower, and carries it away), then they cover the trenches with soil, and plough over them as in dry level ground.

If such trenches are made with the descent and not across it, then they will be parallel to the rills of water that run upon the surface of the clay under the staple (or upper stratum of soil) and would be no more effectual for draining the hill than the digging of one river parallel to another without joining it in any part would be effectual for draining the other river of water.

This method has been found effectual for a time, but not of long continuance because the trenches are apt to be stopped up and then the springs break out as before; besides, this is a very chargeable work, and in many places the expense of it may almost equal the purchase of the land.

It is better to plow drainage ridges across the hill, like French drainage: these tiny ditches bring the water to the edge of the field where the parting furrows lie open and drain down the hill; it is best to make the bottom of these furrows as deep or deeper than the surface of the clay understratum

Therefore it is a better method to plough the ridges across the hill, almost horizontally, that their parting furrows lying open, may each serve as a drain to the ridge next below it, for when the plough has made the bottom of these horizontal furrows a few inches deeper than the surface of the clay, the water will run to their ends, very securely, without rising into the mould, provided no part of the furrows be lower than their ends.

These parting furrows and their ridges must be made more or less oblique according to the form and declivity of the hill, but the more horizontal they are, the sooner the rain-water will run off the lands because the water will then run to the furrows and reach them at right angles, which it will not do when the ridges (of lands) are oblique. But, when oblique, the water's course across the lands will be longer. Every one of these horizontal trenches receives all the water from the rills or

mariculture will prove to be of greater importance – as will the breeding of salt-tolerant foods. –A.B. & M.C.

[323] This is a technique called "French drainage." –A.B. & M.C.

little cutter wherein the water runs betwixt the mould and the clay; these are all cut off by the trenches, which receive the water at their upper sides, and carry it away, as the gutters placed under the eaves of a house do carry away the rain water.

Water runs off a hill both on top of the top stratum and on top of the bottom stratum

The natural course of water being downwards, it would always run by the nearest way to the bottom of the hill, if nothing stopped it. But the water runs from a hill in two manners: upon the surface of the staple, and upon the surface of the clay that is under the staple. That which runs under keeps its straight course from the top to the bottom of a hill, even under a ridge that is made exactly with the descent of the hill (except that part of the water that rises up into the mould and a very little that soaks into the furrows). When the furrows are not made exactly with the descent, the more oblique they are to the descent, the longer will be the water's course under the ridges; and the shorter, as they are nearer being at right angles to the descent. It is also the same with the water that falls upon the surface of the ridges, for the more horizontal they are, the shorter its course will be from them to the furrows which carry it off; and the less of the water will sink into the ridges, the less oblique and the nearer to right angles to the descent they are made.

The use of terraces facilitate better drainage ridges

If there were no other manner of plowing ridges on the sides of hills than what is commonly practiced on the plains, this method of leaving open furrows (or drains on declivities) would be impracticable; because the plough could not turn up the furrows against the hill, and against the ridge also, from the lower side of it: but the easy remedy against that inconvenience is to plough such ridges in pairs without throwing any earth into the trenches. Then the ridges will be plain at the top, and the rain-water will run speedily downward to the next trench, and thence to the head-land, and so out of the field. These trenches will be made, as well as kept, always open, by this plowing in pairs, and is abundantly more easy than the way of plowing ridges singly. [326]

[326] The construction of terraces, besides making a hill easier to plow, will facilitate the use of drainage ridges.

A terrace is a section of the hill that has been leveled through the use of retaining walls and digging into the incline of the hill. Several terraces in succession make an otherwise highly inclined hill into useable strips of a desired width and give it a step-like appearance. Those farmers using tractors will necessarily have wider terraces than those using hand tools. As water runs down the hill, it is possible to include on the wall-side of the terrace the drainage ridge (possibly reinforced with the retaining wall itself).

Terracing without walls is sometimes necessary for lack of affordable material for wall construction. In those cases, the hill is still leveled into sections, but the division between sections has an incline that is greater than the natural (or original) inclination of the hill. If the divisions are allowed to grass over or be covered with permanent retaining vegetation, they are just as effective as walls – especially if at the top of each of the divisions there is a drainage ridge servicing the next-higher terrace and the drainage ridge is grassed over as well.

In terraces, it is possible to install French drainage without fear that it will be destroyed by tillage, as it will simply become a kind of reinforced and permanent ridge. –A.B. & M.C.

This plowing in pairs prevents also another inconveniency which would otherwise happen to these horizontal ridges, namely they being highest in the middle the rain water could not run freely from the upper half of a ridge towards the next furrow below it, but would be apt to sink in there and soak through the ridge. When the ridges lie in pairs, the water will run off from a whole ridge, as well as off the lower half of a ridge that is ploughed singly, and highest in the middle.

Note that every time of plowing, the pairs must be changed, so that the furrow, which had two lands (or ridges) turned towards it one time, must have two turned from the next time: this method keeps the surfaces of all the ridges (or lands) pretty near even .

Do not till with the hill, as it is dangerous to the farmer and the animal (or tractor) besides being ineffective at moderating soil moisture and temperature

Farmers are at more trouble and pains to drown such land (it being common to break their horses' wind in plowing up hill) than they would be at if they laid their ridges in the above said manner, which would effectually make them dry. Many hundred acres of good ground are spoiled, and many a good horse, in plowing against the hill, and against all reason, demonstration, and experience too, which might be learned even from the Irish, who drain their bogs and make them fruitful, while some English bestow much labor to drown and make barren many of their hills, which would more easily be made dry and fertile.

Water does not impoverish land, but enriches it – except when it stands upon the land or runs too swiftly off it. Slow draining water is very good for crops, so long as it is not allowed to flood them

I have observed, that such a hill when ploughed with the descent the wettest never produced anything that was sown on them became the very richest soil was made dry by plowing across the descent. This shows that water does not impoverish land, but the contrary; while it stands upon the land, it prevents the heat which is necessary to the production of most sorts of vegetables and where it runs swiftly, it carries much earth away with it. Where it runs slowly it deposits and leaves much behind it.

Few farmers will undertake experiments to drain their lands with ridges – even with demonstrations – because of Virgil's philosophy against change

Though, in all places where this way of making the ridges across the descent of hills is practiced the land becomes dry, very few farmers will alter their old method. No, not even to try the experiment! But yet they will still complain their ground is so wet and spewy that it brings them little or no profit and if the year prove moist, they are great losers by sowing it.

Of such force is that precept of Virgil's *Cultusque, habitusque, locorum (praediscere)*[327] that seldom is the prejudice of it removed by reason. But some of late are convinced, by observing that a hill of

[327] "Culture, habits, character, station, place and home are learned in advance.," meaning they are born into, reflecting an unstoppable continuity of stagnant existence. Translation by Aaron Brachfeld

mine has been made dry by this means for fourteen years past which before was always more wet and spewy than any field in the neighborhood. From the time of its enclosure out of the heath (or common) and the conversion of it to arable land (which was about seventy years ago), it had been reputed as little better than barren on account of its wetness, and yet now it has been the most profitable field of my farm ever since it has been under this new management. I have also another field that lies about a mile and a half from me. It does not belong to the farm where I live, but was thrown upon my hands (no tenant caring to rent it) because great part of it was full of springs and barren. This also having been kept in lands plowed across the descent (which is but a small declivity) has become dry and now the most prejudiced farmers agree that keeping the lands or ridges of wet ground always cross the descent cures its spewyness.

Some have now attempted to put this method in practice on their wet land, and after it had been well tilled up uphill and down, have plowed it the last time for sowing of wheat in flat lands across the descent; but, by mismanagement, their furrows are higher at each end than the middle, so that none of the water can run off either downwards or sideways, or any other way. Had the furrows carried off the water at both or either of their ends, it might have been effectual, notwithstanding that their ground has a much less declivity and is much less spewy than my hill was. They will doubtless find their mistake and amend it having a precedent before their eyes; but, if they had none within their own inspection, I question whether this mismanagement might not discourage them from prosecuting their project any further.

The benefit to strong land is very great, even if it is not spewy

The benefit of laying up strong deep land into ridges is very great, even if there are no springs in it, as are in the hills aforementioned.

This land, when it lies flat and is plowed in the Virgilian manner by cross plowing (first one way, then the other) retains the rain-water a long time after it soaked into it. By that misfortune the plow is kept out two or three weeks longer than if the same were in round ridges. Indeed, sometimes its flatness keeps it from drying till the season of plowing (and even of sowing) is lost.

Common objections to ridges: 1: they prevent the (fancied) benefit of Virgilian cross plowing, 2: farmers believe they lose part of their ground by leaving some of their land in ridges rather than in crops. Answer: cross-plowing is injurious, as has been previously demonstrated in other chapters, and the ridges make the land more useful and productive, even if they do occupy some of the surface – besides, the ridges increase the surface area of the land, and allow more space for crops

The reasons commonly given against such ridges are the following:

I. They prevent the fancied benefit of cross plowing

II. Farmers think they lose part of their ground by leaving more furrows betwixt ridges than when they lay their land flat because on flat lands, the beds are made much larger than beds on round ridges can conveniently be made, and also because the furrows between ridges must be broader and lie open on hills while on flat lands the furrows fill up by the harrows.

The first of these objections I have already answered elsewhere by showing that cross-plowing is oftener injurious than beneficial.

The second I shall sufficiently confute if I can make it appear that no ground is lost and much may be gained, by ridges.

What I mean by gaining of ground is the increasing of the soil's surface: if a flat piece is plowed into ridges, and if in each sixteen feet breadth there be an empty furrow of two feet, by the height and roundness of the ridges, they have eighteen feet of surface capable of producing corn. If the piece were flat, there would be one-eighth part of profitable ground, or surface, gained more than it had when level: this, I believe, experience will prove if the thing were well examined into.

Another objection: hills, when brought to terraces, will not have the same surface area as had the land been level entirely. Answer: that fewer plants may stand on an acre does not mean that less production will be yielded; and because they eat soil, and hills have more soil, it is just as likely that hills can be more productive than flat lands; and if planted in rows that follow the curve of the hill, no loss in row feet is observed

But against this increase of profitable ground there is an objection which I must not call a frivolous one, in respect to the authors who bring it; yet I hope the desire of finding the truth, will justify me to examine it, and the arguments brought to sustain it.

This opinion of theirs is founded upon their notion (which I think very erroneous) of the perpendicular growth of vegetables, and is, by Mr. Bradley, set in its best light, in his Volume I. pages 8 through 13, and in his cuts, representing three hills. But his arguments seem to be such as all arguments are which pretend to prove a thing to be what it is not, that is, sophistical ones.

The hypothesis he endeavors to prove is in page 8:

"*a hill may contain four equal sides, which meet in a point at the top; but the contents of these four sides can produce no more, either of grain or trees, than the plain ground upon which the hill stands or has its base; and yet by the measure of the sides, we find twice the number of acres, rods, and poles, which measures in the base or ground-plot; and therefore, page 9, hills are worth no more than half their superficial measure, i.e., two acres upon the side of the hill to pay as much as one upon the plain, provided the soil of both is equally rich.*"

To prove it he gives an example in figure 3 of buildings upon a hill, showing that the two sides of the hill will only bear the same number of houses that may stand in the line at the base.

This is foreign to the question of how much grain or how many trees the hill will produce. For vegetables being fed by the earth require much more of its surface to nourish them than is necessary for them to stand on while buildings require no more of the surface but room to stand on. Therefore, no such argument taken from buildings can be applied to vegetables.

The argument of Mr. Bradley's gives no more satisfaction to the question about producing of vegetables, than a grazer would do, being asked how many oxen a certain pasture-ground would maintain, if he should answer, by satisfying you with the number of churches which might stand thereon.

The like answer, in effect, may be given to the argument in Fig. IV. of the plates, only he has forgot to show, that to mound over the hill would require double the rails, or double the hedge-wood

(except stakes) as to mound the base; if it did not, the hill would be yet of the more value, because thereon more surface might be fenced in at less expense.

In Figure II. he gives no good reason why the hill should not bear twice the number of trees as the base can do; for there is as much room for two hundred trees on the hill, as for one hundred on the base, because he allows the surface to be double to that of the base. He ought to measure the distances of trees on the hill, by a line parallel to the surface they grow on, as well as he does the distances of those below!

And suppose the row at the base, together with the surface they grow on were raised up so that it should become parallel to half the row on the hill, would not the trees in the base row be twice as near to one another as the trees in the hill row are? And suppose a line had been tied from the tops of all the lower trees before the row was so raised up at one end, and then, after the situation of the row was so altered, if by this line the trees should be pulled from being perpendicular to the surface they grow on, and made to stand oblique to that, and perpendicular to the horizon, as the upper trees are, would the distances of the trees from one another be altered by this change of posture? No, for their bottoms would be at the same distances, because not removed; and their tops, because the same line holds them, at the same distances in both postures.

Mr. Bradley's lines, drawn from the trees below, which are one perch asunder, make the two rows of trees, falsely, seem to be at equal distances, because those lines are parallel to each other. But this is a deceit; for in truth, the distances of the trees are not measured by the distances of those lines, but by the extreme points at the ends of the lines, and those two points above, where the lines cut the row obliquely, and at unequal angles, are twice as far asunder as the endmost or extreme points below are where the lines cut the row at right angles.

Hence may be inferred that there is room for twice as many trees to grow on the ill as on the base, and twice as much grain, for the same reason, and because there is twice the surface for the roots to spread in. And since Mr. Bradley allows the hill to contain two perches to one of the base, and the soil of both to be of equal goodness, and yet affirms, that the two can produce no more of grain or trees than the one perch can, I cannot see why it should not be as reasonable to say that two quarters of oats will maintain a horse no longer, nor better, than one quarter of oats of equal goodness, will do.

In page 13 he concludes thus: "that hills, in their measure, contain only as much profitable land as the plain or plot of ground they stand upon; and as a proof of that, all vegetables or plants have an erect method of growth."

This proof of Mr. Bradley's is founded upon an argument which has no consequence, unless it were first proved that the surface of earth could produce and maintain as many vegetables or plants as could stand thereon in an erect posture. But this supposition is as impossible as the suggestion that half an acre should produce and maintain a hecatomb[328] without Mr. Bradley's teaching oxen to live upon air for their food, as he thinks Van Helmont's tree did.

Even experienced farmers need to be convinced that a plant stands above the soil upon only a small part of the soil it uses

All expert husbandmen must be convinced that the greatest crop of vegetables that ever grew might stand in an erect posture upon a twentieth (and I may say the hundredth) part of the surface

[328] Hecatomb: An ancient Greek sacrifice of 100 cattle. —A.B. & M.C.

that produced it; therefore, there must be nineteen parts (for the roots to spread) unoccupied by the trunks, stems, or stalks.

And though it is true that a hill will support no more of these (than its base) when placed in an erect posture close together (as in a sheaf) yet this close position is only proper for them when they are dead and require no more nourishment from the soil. Therefore, this argument of Mr. Bradley's must not be admitted in vegetable growth, where there is always required nineteen times more room in the surface for the use of the roots than what the stems, trunks, or stalks, do possess upon it.

It must be concluded that the more room there is for the roots, the greater number of plants may be produced.

While not every plant has the same above-ground growing habits, beneath the ground, every plant – even those with taproots – have horizontal roots

I cannot even admit that all vegetables or plants have an erect method of growth because the contrary is seen in chamomile, and many other vegetables which have a horizontal method of growth.

But what is more material to this purpose to be observed is that all vegetables have horizontal roots, and roots parallel to the earth's surface or superficies. And unless those roots have a sufficient superficies of earth to range in for the nourishment of the plant, the stems and branches cannot prosper whatever be their method of growth above the earth, and if there is not a due quantity of food for the roots within the earth, a very little space will soon contain the external parts of vegetables dead upon it.

From what has been said I think we may conclude that Mr. Bradley's hill may produce more vegetables than the base whereon it stands and, therefore, it is of more value than half its superficial measure, (two acres). Two acres on the hill is worth more than one acre on the plain, the soil being equally rich, as he allows it to be, in his case.

Now, indeed, whether Mr. Bradley might not possibly be deceived in his opinion of the equal richness of is hill and his plain I will not dispute; I will only say this, that it is generally otherwise. But where a plain is plowed up into moderate ridges, whose ridge height is in proportion to the depth of the staple (below which the plough must take nothing into the ridges), the soil is equally rich whether it be ploughed plain or ridged up. And, as the surface is in the ridges increased, there is nothing in all Mr. Bradley's arguments that shows why that increased surface should not produce more vegetables than the same earth could do whilst it was level.

Other reasons why a ridged hill will produce more, besides the increased soil area: it is free from the injuries of too much water, it is better protected against cold winds (because the ridges are a shelter to one another), if the surface is exhausted for whatever reason, the ridges may be made where the beds were and the soil will be drier in wet weather and moister in dry weather

There are other reasons why it should produce more when ridged, besides the increase of surface:

I. It is then more free from the injuries of too much water.
II. It is better protected against cold winds; because the ridges are a shelter to one another.
III. If the surface be much exhausted by too frequent sowing, the ridges may be made just where the furrows were and then the surface will be entirely changed.

To the three we may add a fourth reason: raising the thickness of the staple in the ridges keeps the surface drier in wet weather and moister and the bottom of the staple in dry weather. And I have seen barley that was drilled on my raised little ridges flourish in a dry summer on the brow of my chalky hill, and on my lowest land in wet weather when the barley hand-sown contiguous to it on each side of those ridges, sown on the level the same day that the ridges were drilled look yellow and sickly, even though it is not wet land.

General rules for ridges: their height must depend on the nature of the soil and the difficulty it admits water: the more difficult water is admitted, the taller the ridges should be; the taller the ridges, the wider they should be to avoid erosion

The following general rules ought to be observed about ridges.

As to their height, regard must be had to the nature of the soil in the difficulty that it admits water; for the greater that is, the greater declivities the ridges should have. And then, if the soil is not deep, they should generally be made the narrower.

Hills with ridges receive more benefit from dew, having more surface area

There is one thing which Mr. Bradley takes no notice of: that no more of the rain, or other benefits of the atmosphere which descend perpendicularly can fall on a hill, or on a ridge, than what would fall on the base, or ground-plot. But, it is probable, that more fine vapor, which swims in the current of the air horizontally strikes and breaks against those eminences to make an equivalent of extra rain (except that it runs off more quickly).

Notwithstanding all that can be said in benefit of ridges, land that is naturally suited for agriculture is better; wider aisles are better and wide aisles are difficult to have on hills.

Notwithstanding all I have here said in behalf of ridges, I must confess that for my hoeing-husbandry, I should prefer land that is naturally dry enough without a necessity of being laid up in any larger or higher ridges than what may contain six feet in breadth, the size being the largest that is proper for the regular operation of the horse-hoe, whether the rows be double, triple, or quadruple.

Ridges separated by 6 feet are ideal (on either side of a single row and 6 foot aisle), but even narrow ridges (every 5 or 4 feet) can be advantageous as well in preparing the ground to be worked early in the spring

Since the printing of my Essay, I find upon trial that these narrow ridges are as effectual as any for carrying the water off from my clayey hill; and that they may be made much less horizontal than broad ridges, whereby their furrows are the more easily turned upwards against the declivity.

I have not tried any narrower ridges than six feet upon this hill, but I have had full experience of five feet and of four feet ridges upon other lands and find that all sizes of these narrow ridges are very advantageous even where the crop is to be sown upon the level because fewer furrows are necessary for the filling of an acre when it is kept in such ridges than in broad lands, and after wet weather, the ridges are fit to be plowed much sooner than level ground.

CHAPTER NINETEEN:
OF DIFFERENCES BETWEEN THE OLD AND THE NEW HUSBANDRY AND MODERN ECONOMIC ANALYSIS OF THE TULLIAN AGRICULTURE

Not all old husbandry is Virgilian, but the new husbandry is that which was developed by Jethro Tull

I do not say that every species of old husbandry is Virgilian. When land of all sorts is plowed five or six times with due intermissions instead of once or twice it is rather Anti-Virgilian, though not the horse-hoeing method, which I call the new husbandry, because it has not been practiced since I first developed it fourteen years ago (that I know of).

Comparing the expense, goodness, certainty and sustainability of the old and new methods

In order to make a comparison between the hoeing husbandry and the old way, there are four differences that ought to be very well considered.

I. The expense of a crop
II. The goodness of a crop
III. The certainty of a crop
IV. The condition in which the land is left after a crop, or the ease by which production is sustained

I. Of the different expense of a crop: profit comes not only from the revenues of the total crop's production, but the cost of producing that crop; a farmer can produce more but retain less profit than a farmer who produces less, Tullian agriculture increases revenues and decreases costs

The profit or loss arising from land, is not to be computed only from the value of the crop it produces, but from its value after all expenses of seed, tillage, etc., are deducted. [329]

Thus, when an acre brings a crop worth four Pounds and the expenses thereof amount to five Pounds, the owner's loss is one pound; and when an acre brings a crop which yields thirty shillings and the expense amounts to no more than ten shillings, the owner receives one Pound clear profit from this acre's very small crop even while the other loses one Pound by his greater crop.

[329] Profit = revenues − expenses. —A.B. & M.C.

The whole Expense of an Acre of sown Wheat in the Old Husbandry: 4 £ 10 s

	£	s.	d.
In seed and Tillage, nothing can be abated of ...	1	3	6
For the Weeding, one year with another, is more than	0	2	0
For the Rent of the year's fallow	0	10	0
For the Dung; it is in some places a little cheaper, neither do they always lay on quite so much; therefore abating fifteen shillings in that article, we may well set dung and carriage at...	2	10	0
Reaping commonly five shillings, sometimes less	0	4	6
Total:	4	10	0

The usual expenses of an acre of wheat, sown in the old husbandry, in the country where I live, is, in some places, for two bushels and a half of seed while in other places four bushels and a half; the least of those quantities at three shillings per bushel, being the present price, is seven shillings and sixpence. For three plowings, harrowing, and sowing, sixteen shillings; but if plowed four times, which is better, one Pound. For thirty loads of dung to a statue acre is two Pounds, five shillings. For carriage of the dung, according to the distance, from two shillings to sixpence per load; one shilling being the price most common, is one Pound ten shillings. The price for weeding is very uncertain, it has sometimes cost twelve shillings, sometimes two shillings per acre.

The price of dung is different in different places, and the price of carriage varies according to the distance. It would cost me much more than fifty shillings to buy dung and hire the carriage of it for an acre and in many places the expense of it is greater yet (though Equivocus is pleased to set the price at from forty shillings to forty-four shillings for an acre).

In his essay for June, p. 61, Equivocus sets dung at two shillings a load, and then thirty loads to an acre, which are commonly laid, and thirty shillings for carriage, and spreading makes the expense of dunging an acre amount to four Pounds ten shillings. And he says that in a dry summer dung may burn up and spoil the crop.

Were I to buy dung at the nearest place where any is to be sold, the very carriage of it to my land would be worth above five Pounds for each acre.

Equivocus, in his Essay for May, p. 228, says, land that had been the most dunged brought the worst crop of corn.

He says the dung, being aged for two years, ought to be reckoned but half to the first year. In answer to this, I say that though it may be as he alleges in the common husbandry, in this comparative calculation the whole expense of dung must be charged to the first year because a crop sown in the common manner upon the level, following a hoed crop without dung, is always as good or better than when sowed the next year after a dunged sown crop.

Folding of land with sheep is reckoned abundantly cheaper than cart-dung, but this is to be questioned because much land must lie still for keeping a flock (unless there be downs) and for their whole year's keeping with both grass and hay, there are but three months of the twelve wherein the fold is of any considerable value. This makes the price of their manure quadruple to what it would be if it were equally good all the year, like cart-dung. And besides which, folding sheep yields little profit besides their dung because the wool of a flock, except it be a large one, will scarce pay the shepherd and the shearers.

But before discounting sheep dung too greatly, consider that there is another thing which enhances the value of keeping sheep, namely the dunging of the land with their bodies when they all die of the rot, which happens too frequently in many places. But in this case, the whole crop of corn must go to purchase another flock, which may have the same fate the ensuing year if the summer prove wet.

Consider that the farmer may be so served by sheep for several successive years unless he should go bankrupt and another take his place, or unless dry summers come in time to prevent it. To avoid this misfortune, he would be glad to purchase cart-dung at the highest price for supplying the place of his fold, but it is only near cities and great towns that a sufficient quantity can be procured.

But wait! Suppose the price of dunging to be only two Pounds ten shillings, and the general expense of an acre of wheat, when sown, as three shillings per bushel, or four Pounds ten shillings with the year's rent of the fallow. The expenses of planting an acre of wheat in the hoeing husbandry is three pecks of seed, and at three shillings per bushel, is two shillings and three pence. The whole tillage, if done by horses, would be eight shillings because our two plowings and six hoeings are equal to two stirrings, the common price whereof is four shillings each. But this we diminish half when done by oxen kept on sanfoin (land, worth thirty shillings rent, drilled with sanfoin, will well maintain an ox a year, and sometimes hay will be left to pay for the making). In any case, we cannot allow more than one shilling per week for oxen work, because oxen keeping comes but to seven pence a-week round the year.

They who follow the old husbandry cannot keep oxen so cheap because they can do nothing without the fold, and store-sheep will spoil the sanfoin. They may almost as well keep foxes and geese together, as store-sheep and good sanfoin! Besides, the broadcasted sanfoin costs ten times as much the planting as drilled sanfoin does, and must be frequently manured or else it will soon decay – especially upon all sorts of chalky land, whereon it is most commonly sown.

The expense of drilling cannot be much; for, as we can hoe six acres per day, at two furrows on each six-foot ridge, so may we drill twenty-four acres per day with a drill that plants two of those ridges at once. And this we may reckon three halfpence an acre. But because we find it less trouble to drill single ridges, we will set the drilling, at most, at sixpence per acre.

As every successive crop (if well managed) is more free from weeds than the preceding crop, I will set it altogether at sixpence an acre for weeding. And this may be enough, if the land be well cleansed the year before, and considering that several years in such there is no occasion for weeding at all: and as this calculation is comparative with the old way, we should examine the price of weeding the sown corn, which by the best information I can get is, this year, 1735, about 4 shillings per acre for weeding of barley, and of wheat round about where I live about 6 shillings and in Wiltshire 15 shillings per acre for their wheat. We will not consider the great damage is done by the feet of the weeders, and the damage from the weeds which are left despite the efforts of the weeders.

For a boy or a woman to follow the hoe-plough and uncover the young wheat when any clods or earth happen to fall on it, which trouble is seldom necessary above once a crop, two pence an acre.

One penny is too much for brine and lime for an acre.

Reaping this wheat is not worth above half as much as the reaping of a sown crop of equal value because the drilled stands upon about a sixth part of the ground, a reaper may cut almost as much of the row at one stroke, as he could at six, but if the same stood dispersed all over the ground, as the sowed does. And because he who reaps sowed wheat, must reap the weeds along with the wheat; but the drilled has no weeds; and besides, there goes a greater quantity of straw, and more sheaves, to a bushel of the sowed, than to the drilled. And since some hundred acres of drilled wheat has been reaped at two shillings and sixpence per acre, I will count that to be the price.

One sheaf of the latter will yield more wheat than two of the former of equal diameter.

The whole Expense of an Acre Wheat in the New Husbandry: 10 s.

	£.	s.	d.
For seed	0	2	3
For tillage	0	4	0
For drilling	0	0	6
For weeding	0	0	6
For uncovering	0	0	2
For brine and lime	0	0	1
For reaping	0	2	6
Total:	0	10	0

The whole Expense of an Acre of Wheat in the Old Husbandry (from previous table)

The expense of an acre of sowed wheat is ...	4	0	0
To which must be added, for the year's rent of the fallow ...	0	10	0
Total:	4	10	0

Insert of the 5th Edition to Tull's Work: a Comparison to Modern Farming Methods: Tullian methods outperform modern ones

Tull is wronged by Dr. Warkentin who, in his poorly researched article, whose faults have already been explored at length, especially concerning his inability to read those works which he cites, demonstrates again his ineptitude in research when he claims Tull could expect a yield of 16 bushels per acre. Especially when, in the Chapter on Wheat, he easily expects 48 bushels per acre.

But let us right this wrong and compare directly Tull's ancient method with the modern farming methods, as Dr. Warkentin attempted to do.

Since the monetary conversion between 1998 US Dollars and Jethro Tull's Shillings is impossible to compute, we will employ the theory that the relative price of wheat does not vary much over the centuries to estimate the relative value of 1735 shillings and 1998 US Dollars.

Giving Dr. Warkentin the benefit of the doubt, we have accepted his erroneous claim that Tull produced 16 bushels per acre.

Yet it is difficult to be so generous when we examine the work of Dr. Grant Jackson of Montana State University (of the Western Triangle Ag Research Center, Conrad) who examined the response of wheat to nitrogen in "*Predicting Spring Wheat Yield and Protein Response to Nitrogen*" (1998). Dr. Jackson usually expects on his fields between to 36 to 56 bushels per acre. Averaged, this results in 46 bushels per acre. The average yield in the USA in 2009 according to the USDA was 44.4 bushels per acre. We will use Dr. Jackson's figure for the conventional yield and compare them against Dr. Warkentin's figures for Tull, and then correct Dr. Warkentin's figures using Dr. Jackson's figures (doing what background research Warkentin ought to have before presuming what yield Tull should have seen), and then we will see that Tull's figures themselves are accurate and should not have been doubted by Dr. Warkentin – especially when Dr. Warkentin offers so many reasons to doubt his own work.

We'll start with seed costs.

Tull uses 3 pecks = 0.75 bushels of seed and, with the 2007 price of wheat at (about) $4.50 per bushel, this has Tull paying $3.38 per acre. By this relationship of costs, we compute here that Tull's three shillings per bushel makes each of his shillings worth about $1.50 per shilling. Dr. Barry Ward of Ohio State University Extension estimates in his *Wheat Production Budget 2009* that seed costs $31.50 per acre for a usual wheat farmer in Ohio.

Before we continue, let us put aside any doubt that $1.50 is not too high an estimate for shillings, or unexpected. Though shillings are worth less today, the relative value of grain is the same: the price of staple grains will remain fairly constant in relation to other costs within a currency over time, even with technological improvements and industrialization. So how did grain become relatively worth less? David Ricardo proved that a rise in the rate of profit can only be brought about by lowering real wages. Nobuo Okishio, a Japanese economist argued "if the newly introduced technique satisfies the cost criterion [i.e. if it reduces unit-costs, given current prices] and the rate of real wage remains constant, then the rate of profit must increase" (Okishio, 1961, p. 92). Assuming a constant level of real wages, technical change would lower the production cost per unit, thereby raising the innovator's rate of profit. The price of output would fall, and this would cause the other costs to fall also. The new (equilibrium) rate of profit would therefore have to rise. By implication, the rate of profit could in that case fall only if real wages rose in response to higher productivity. In short, more grain is being produced today per unit of labor, on average, than in 18th Century England.

This allows a great segue into examining Tull's labor costs and comparing them with modern ones. First, to consider the cost of Tull's oxen.

Tull pays for his oxen 30 shillings in rent ($45) per year for food, earning enough to pay for the labor in producing the hay in profit. These days, hay land is rented for about 25% of the crop, which in many places 4 tons of hay per acre is usual, and so Tull's number is fairly accurate with hay prices at $80-$120 per ton being seen depending on the year. Of course, some hay fetches only $50 per ton, and some hay earns even $200 per ton, but we will show this matters little: oxen will eat about 20 lbs of hay per day, about 1.65 tons per year (41% of the first acre's harvest). With 4 tons easily grown per acre, more than 1/3 of the hay crop of the first acre could be sold to cover the costs of production. If more than 1 acre were rented per oxen, the operation would have a net gain to the entire farm. We'll account Tull having paid nothing, in the end, for his oxen. Though this handicaps Tull further, it will be of little matter later.

Let us compare the cost of the ox to the cost of tractors. Using the same Ohio report we learn that tractors cost $61.04 per acre for grease, fuel, oil, repairs, and machine and equipment charges.

Tull plants 6 acres per day at 1.50 pence per acre. In Tull's time, there were only 12 pence per shilling (now there are 100): this amounts to $1.50/shilling x (1.5/12) = $0.19. To discount the possibility that labor was cheaper then we'll valuate it on a per-hour basis. Tull performs planting at 24 acres per 10-12 hour day with a single laborer planting 3 acres per hour. The US Department of Labor estimates that experienced farm workers earn $8.05 per hour (inexperienced earn $6.76 per hour) (*The National Agricultural Workers Survey*, 2006). Thus, Tull's costs for planting amount to $24.15 plus seed.

If a farmer were using a tractor in Tull's method, they would spend 75% less on all mechanical and labor costs (as described later in this chapter) except tillage because they are working less than 25% of the ground of conventional farmers.

Fertilizers, pesticides and herbicides...

Ohio's low-end estimate for fertilizers is $90.27, but Tull requires none.

Ohio's low-end estimate for pesticide and herbicide is $23 per acre, but Tull requires none.

Tull does require 6 pence per acre for weeding, or $1.50/shilling x (6/12) = $0.75. In modern times, according to the Delta Farm Press (*Weeds controlled by fire in niche soybean market*, June 4th, 2004) the costs of mechanical cultivation are estimated at $7 per acre (Tull did not have the advantages of a mechanical cultivator to tow behind his ox, but we will give him that advantage in comparing his method to modern methods).

Extra tillage.

Tull requires a labor expense in hoeing of 2 pence per acre, or $1.50/shilling x (2/12) = $0.25, and additional labor expense of 2 shillings, 6 pence per acre for harvesting ($1.50/shilling x (30/12) = $3.75. Translated into modern terms, we will estimate these by the cost of cultivation ($7 per acre) multiplied by 8 hoeings and 1 harvesting ($63) if the farmer is using a tractor. However, because the oxen method has it's "fuel" prepaid in this estimate, requiring only labor, we look at Tull's estimate for planting 6 acres per day, considering that only 1/4 to 1/2 of the land is worked during planting, and estimate only 2-3 acres could be tilled per day. An 8 hour day brings this cost to 2.5 acres x $8.05 per hour = $20.13. Tull claims to be able to work 2 acres per hour, so this is somewhat of an overestimate. Ohio undertakes a "no till" system, but requires $24.30 per acre for labor costs.

	Tull Unmechanized	Modern Conventional	Tull Mechanized
Tractor or Oxen	$0	$61.04	$61.04
Planting Costs	$27.53	$31.50	$7.88
Fertilizers	$0	$90.27	$0
Chemicals or weeding	$7	$23	$5.75
Tillage or labor	$20.13	$24.30	$63
TOTAL COSTS:	**$54.66**	**$139.84**	**$137.67**

REVENUES: 16bu x $4.50 = $72 46bu x 4.50 = $207 $16 x $4.50 = $72

At first we would conclude, as Dr. Warkentin did, that Tull's method is out of date. But we are using Dr. Warkentin's yield numbers, and they are baseless and quite wrong. We'll begin by correcting Dr. Warkentin's yield numbers.

First, in Table 7 of Dr. Goss's excellent work, it is reported that under plowing there is an annual mineralization of 82.9 kg/ha, with a standard error 10.7 kg/ha. This is 182.76 lbs / 2.47 acres, or 74 lbs/acre. Using Dr. Jackson's nitrogen response calculations, a low yield would be (Yield = 21.0 + 0.18 N - 0.00051 N^2 = 32 bu/a) and a high yield would be (Yield = 30.2 + 0.31 N - 0.0003 N^2 = 52 bu/a). An average of 42 bushels per acre. Recomputed, they are:

	Tull Unmechanized	Modern Conventional	Tull Mechanized
REVENUES:	**42 bu = $189**	**46bu = $207**	**42 bu = $189**
PROFIT:	**$134.34**	**$67.16**	**$51.33**

This brings up a serious consideration for those who would use fertilizers. Even Dr. Warkentin understands that "the concern is more often with limiting the amount of nitrate in soils." Apparently, the best way to do this is to not apply them to the soil in the first place.

Dr. Warkentin, if he had read Jethro Tull's work, would have seen that 16 bushels per acre is not usual for him, and Tull actually usually produced 48 bushels per acre (*"a yard in length of my treble row of the third successive crop of wheat, without manure or fallow, produced 20 ounces of wheat which, allowing six feet to the aisles, is about 48 bushels to the acre*" – from the Chapter on Wheat), and that the 16 bushels that he imagined (*"I have not had an acre yet that was tolerably well managed that produced much more than 16 bushels per acre!*" – also from the Chapter on Wheat) was actually not usual for Tull who had "much more than 16 bushels per acre." We may perhaps understand that Warkentin might have been skeptical of Tull's claims, but, regardless of what Warkentin thought Tull stated, he should have understood that it was reasonable to expect something closer to 42 bushels because so much nitrogen was being mineralized, observed that Tull's claims were nearly equal to what could be reasonably expected and accepted that Tull was, as he had been previously in his book, an impartial objective reporter of fact. Revising Warkentin's figures further with Tull's measurements we find:

Profit per Acre of Wheat in Unmechanized Tullian ($161.34), Mechanized Tullian ($78.33) and Modern Conventional ($67.16) using low yields for Tullian systems

	Tull Unmechanized	Modern Conventional	Tull Mechanized
REVENUES:	**48bu = $216**	**46bu = $207**	**48 bu x $4 = $216**
PROFIT:	**$161.34**	**$67.16**	**$78.33**

While adding nitrogen is not a concern for Tullian agriculture, it is one for conventional agriculture, which pays for nitrogen dearly. Tull usually harvested 48 bushels per acre, and could sometimes expect more than 80 (*"The greatest produce I ever had from a single yard in length, of a double row, was eighteen ounces: the partition of this being six inches, and the interval thirty inches, was, by computation, ten quarters, or 80 bushels to an acre."* –from this chapter) without any added nitrogen.

5th Edition Insert, Continued: reducing planting density can increase total production

How is 80 bushels to an acre possible with no fertilizer?

How did Tull wind up with just under twice to just under three times more yield per acre than Dr. Jackson would expect?

By reducing planting density. With fewer plants per acre and the same amount of nitrogen, each plant could obtain more nitrogen and produce more. The 2-3 times per acre increase corresponds with the aisle space allotted by Tull: with 2 to 3 times more aisle than row, this results in an equivalent amount of nitrogen approximating 148 to even 222 pounds per acre! By Dr. Jackson's calculations, this could result in about 36 to 84 bushels per acre. To get 80 bushels per acre would simply require Tull reduce the bed/aisle ratio so that there was about 6 times more aisle than row... unless Tull added manure or other sources of nitrogen, or had an exceptional year for nitrogen mineralization, in which case he would need a somewhat reduced aisle to row ratio.

These numbers seem valid: Tull often had 6 times more aisle than row and did not use manure often or at all: with a treble row of wheat extending a foot in width across a bed and 6 feet of aisle between beds, there is 6 times more aisle than row.

Likewise, a similar effect on plant growth when density is low was noticed by Weaver and Clements when ants clear an area about their nest: by reducing competition for water and soil, plants grow bigger on the perimeter of a nest clearing.

But could animal power truly compete with tractors for the total number of acres farmed? Coordinating many teams of animals over many acres is indeed a headache, but it is a small one that is well compensated for. With each team (including humans and animals) more efficient than tractors undertaking a system that is more efficient than conventional systems, the manager can afford medicine for their head.

It is important to note here that should tractors be used for Tull's method, Tull's method requires smaller tractors (necessarily, to achieve beds and aisles of approximately 6 feet or less – we used a JD 4105 with great success, but a smaller one would have been better), but other mechanical means exist including "ATV's" (which come with disk plow attachments, harvesters, seed drills and more), hand-driven rototillers (which we have found to work excellently and profitably) and draft animals (again, we have had success here too, and we would agree with Tull that bovines would probably be wiser than equids). Smaller tractors cost less, and so the numbers borrowed from Ohio might not be perfectly applicable to this situation.

Each kind of engine, whether it is biological, mechanical or a combination, has a peak efficiency that can be measured as a return to cost. This dictates that large acreages require tractors, whereas small acreages require draft animals or even human labor. Extraordinarily large acreages can be farmed with profit using extraordinarily large tractors as easily as small acreages can be farmed with profit using hand labor. Several teams of oxen cultivate what one tractor does at less cost than a tractor could.

And, biological labor is just as or more reliable than mechanical labor, and oxen are cheaper to heal and replace than tractors are to repair and replace. Draft animal equipment is by far much cheaper than mechanized equipment.

The implication that Tull's method is more easily sustained and cheaper to maintain over time is discussed more later. —A.B. & M.C.

Tull, Continued

I am wrongfully accused of partiality by Equivocus for charging the year's fallow to the calculation of the expenses in the old way, and not to that in the new when in the horse hoeing husbandry's successive crops we have no fallow, but in the old there is generally and almost always a fallow for wheat; therefore two year's rent to be reckoned for their one crop.

If I have reckoned the expense of the drilled at the lowest price to bring it to an even sum, I have also abated in the sown expenses more than the whole expense of the drilled amounts unto.

And thus the expense of a drilled crop of wheat is but the ninth part of the expense of a crop sown in the common manner.

It is also some advantage that less stock is required where no store-sheep are used.

In plain plowing, six feet contains eight furrows; but we plough a six-foot ridge with four furrows because in this there are two furrows covered in the middle of it and one on each side of it lies open. Now, what we call one hoeing is only two furrows of this ridge, which is equal to a fourth part of one plain plowing so that the hoeing of four acres requires an equal number of furrows with one acre that is plowed plain, and equal time to do it in (except that the land that is kept in hoeing works much easier than that which is not).

All the tillage we ever bestow upon a crop of wheat that follows a hoed crop is equal to eight hoeings, two of which may require four oxen each, one of them three oxen, and the other five hoeings two oxen each. However, allowing three oxen to each single hoeing, taking them all one with another, which is three oxen more than it comes to in the whole.

But the number of oxen required will be according to their bigness and strength, and to the depth and strength of the soil, which also will be the easier draught for the oxen, the oftener the intervals are hoed.

Begin at five in the morning; and in about six hours you may hoe three acres, being equal in furrows to three rood, i.e., three quarters of an acre. Then turn the oxen to grass, and after resting, eating, and drinking two hours and a half, with another set of oxen begin hoeing again; and by, or before, half an hour after seven at night, another like quantity may be hoed. These are the hours the statute has appointed all the laborers to work, during the summer half-year.

This is the time limited by the words of the statue, but the meaning is to be determined by the unlimited magistrates who put the same in execution. And some of them (and their determination has the same effect as of all) have lately declared, that if a laborer works an hour, he must be paid for a day, which makes some alteration in the price of tillage of all sorts.

To hoe these six acres a day, each set of oxen draws the plow only eight miles and a quarter (which they may very well do in five hours) and then the holder and driver will be at their work of plowing ten hours, and will have four hours and a half to rest, etc.

The expense then of hoeing six acres in a day in this manner may be accounted at one shilling for the man that holds the plow, sixpence for the boy that drives the plow, one shilling for the six

oxen, and sixpence for keeping the tackle in repair. The whole sum for hoeing these six acres is three shillings, being sixpence per acre.

While a farmer who uses the new husbandry earns safely much more than his costs, the farmer using the common method commonly runs in debt to his neighbors, and in arrear of his rent. And if the markets do not rise in time, or if his crops fail in the interim, his landlord seizes on his stock and then he knows not how it may be sold, actions are brought against him, the bailiffs and attorneys pull him to pieces; and then the Virgilian farmer is broke .

II. Of the different goodness of a crop: even poor land will produce well, and good land will produce more, and the quality will be excellent in either case; greatest production Tull ever yielded was 80 bushels per acre

The goodness of a crop consists in the quality of it as well as the quantity; and wheat being the most useful grain, a crop of this is better than a crop of any other corn and hoed wheat has larger ears (and a fuller body) than sowed wheat. We can have more of it because the same land will produce it every year, and even on land which, by the old husbandry, would not be made to bear wheat at all: so that, in many places, the new husbandry can raise ten acres of wheat for one that the old can do because where land is poor, they sow but a tenth part of it with wheat.

We do not pretend that we have always greater crops, or so great as some sown crops are, especially if those mentioned by Mr. Houghton be not mistaken.

The greatest produce I ever had from a single yard in length, of a double row, was eighteen ounces: the partition of this being six inches, and the interval thirty inches, was, by computation, ten quarters, or 80 bushels to an acre.

I had also twenty ounces to a like yard of a third successive crop of wheat; but this being a triple row, and the partitions and interval being wide, and supposed to be in all six feet, was computed at six quarters to an acre. And if these rows had been better ordered than they were, and the earth richer and more pulverized, more stalks would have tillered out, and more ears would have attained their full size, and have equaled the best, they would have surely have made a much greater crop than either of these were.

III. The certainty of a crop: Tullian farmers can yield a substantial crop every year

The certainty of a crop is much to be regarded, it is better to be secure of a moderate crop than to have but a mere hazard of a great one. The Virgilian is often deceived in his expectation when his crop is coming into ear and very big, as well as when it is in danger of being too little. Our hoeing farmer is much less liable to the hazard of either of those extremes, for when his wheat is big, it is not apt to lodge or fall down (which accident is usually the utter ruin of the other), and he is free from the causes which make the Virgilian crop too little.

A very effectual means to prevent the failing of a crop of wheat, is to plow the pulverized earth for seed early and when it is dry. The early season also is more likely to be dry than the latter season is.

Why the Virgilian method is uncertain:

1. The Virgilian is commonly late in his sowing; because he cannot fallow his ground early, for fear of killing the couch, and other grass that maintains his sheep.

2. The Virgilian commonly keeps sheep, which are so necessary to his husbandry and make the Virgilian late in sowing.

3. When the Virgilian is late in sowing, it must not be sowed dry, for then the winter might kill the young wheat. Neither can he at that time plough dry, and sow wet, because he commonly sows under furrow; that is, sows the seed first, and ploughs it in as fast as it is sown.

4. If the Virgilian sows early (as he may if he will) in light land, he must not sow dry, for fear the poppies and other weeds should grow and devour his crop.

5. And if the Virgilian sows early in strong land, let it be sown early, wet or dry (though wet is the worst), it is apt to grow so stale and hard by the spring, that his crop is in danger of starving unless the land is very rich or much dunged and the winter and spring kind.

6. If it is rich land and the winter and spring kind, it may not be in less danger of being so big as to fall down and be spoiled.

7. Another thing is, that though he had no other impediment against plowing dry and sowing wet, it is seldom that he has the time to do it in for he must plough all his ground, which is eight furrows in six feet, and whilst it is wet, must lie still with his plough.

8. And when he sows under furrow, he fears to plow deep, lest he burry too much of his seed, and if he ploughs shallow, his crop loses the benefit of deep plowing, which is very great.

9. When he sows upon the furrow (that is after it is plowed) he must harrow the ground level to cover the seed, and that exposes the wheat the more to the cold winds, and suffers the snow to be blown off it and the water to lie longer on it – all which are great injuries to it.

Our hoeing husbandry is different in all of the fore-mentioned particulars.

1. We can plough the two furrows whereon the next crop is to stand, immediately after the present crop is off.

2. We have no use of the sheep because our ground has annually a crop growing on it and it would have to lie still a year if we would keep sheep, and then a crop would be lost. Besides, all the good the fold could do to the land, would be only to help to pulverize it for one single crop, its benefit not lasting to the second year. And so we should be certain of losing one crop for the very uncertain hopes of procuring one for the ensuing year by the sheep; when it is manifest, by the adjoining crops, that we can have a much better crop every year, without sheep or any other manure.

3. We can plough dry, and drill wet, without any manner of inconvenience.

4. He fears the weeds will grow and destroy his crops: we hope they will grow, to the end we may destroy them. For before they grow they cannot be killed; but if they are all killed as soon as they appear, there will be no danger of their exhausting the land or restocking it with their seed, and it is our fault if we drill more than we can keep clean from weeds by the horse-hoe, hand-hoe, and hands: the first for the intervals, the second for the partitions, and the third for the rows. By the two former, as soon as they appear as they can; but by the last, when they are grown high enough to be conveniently taken hold of.

5. We do not fear to plant our wheat early (so that we plow dry), because we can help the hardness or staleness of the land by hoeing.

6. The two furrows of every ridge whereon the rows are to be drilled, we plow dry. And if the weather proves wet before these are all finished, we can plow the other two furrows up to them until it is dry enough to return to our plowing the first two furrows. And after finishing them, let the weather be wet or dry, we can plow the last two furrows. We can plow our two furrows in the

fourth part of the time they can plow their eight, which they must plough dry, all of them, in every six feet. For they cannot plow part dry, and the rest when it is wet as we can.

7. We never plant our seed under furrow, but place it just at the depth which we judge most proper through experimental evidence. And there is no danger of burying it, for it is pretty shallow, about two inches deep.

8. We not only plow a deep furrow, but also plow to the depth of two furrows; that is, we trench-plow where the land will allow it. And we have the greatest convenience imaginable for doing this because there are two of our four furrows always lying open, and two plowed furrows (that is, one plowed under another) are as much more advantageous for the nourishing a crop as two bushels of oats are better than one for nourishing a horse. And if the staple of the land is too thin or shallow, we can help it by raising the ridges prepared for the rows the higher above the level.

Very little of my land will admit the plow to go the depth of two common furrows without reaching the chalk, but deep land may be easily thus trench-ploughed with great advantage. And even when there is only the depth of a single furrow, that may sometimes be advantageously plowed twice.

9. We also raise a high ridge in the middle of each interval above the wheat before winter to protect it from the cold winds and to prevent the snow from being driven away from our seeds by the winds. And the furrows or trenches, from whence the earth of these ridges is taken, serve to drain off the water from the wheat so that it is drier and warmer than the harrowed wheat, which has neither furrows to keep it dry nor ridges to shelter it, as every row of ours has on both sides of it.

This is a mistake; for the ridges in the middle of the intervals do not always, nor often in thin shallow land, lie high enough to make a shelter to the rows: but when wheat is drilled on the level, it is sheltered by the ridges raised in the intervals.

But we never weed or hand-hoe wheat before the spring.

IV. The condition in which the land is left after a crop, or the ease by which production is sustained: Tullian farming improves land for the next year

The different condition land is left in after a crop by the one and the other husbandry is not less considerable than the different profit of the crop.

Soil well pulverized by the plow for one whole year will produce a good crop: but then, if instead of being sown, it is kept pulverized on for another year without being exhausted by any vegetables, it will acquire from the atmosphere an extraordinary great degree of fertility, more than it had before such second year's pulverization and unexhaustion.

This being granted (which no man of experience can deny) what reason can there be why such a number of plants, competent for a profitable crop, may not be maintained on it the second year that may keep the degree of their exhaustion in equilibrium with that degree of fertility, which the same land had acquired at the end of the first year of its pulverization, the same degree of pulverization being continued to it by hoeing in the same year? Or why may it not produce annual crops always, if the same equilibrium be continually kept?

Two unanswerable reasons may be given why this equilibrium cannot be kept in the broadcasting of seed as it may in the hoeing method. First, in the former, the land is by the number of sown plants and weeds much more (we may suppose at least five times more) exhausted. Second, no pulverization is continued to the soil while the crop is on it, which is that part of the year which is the most proper (if not the only proper) season for pulverizing.

Therefore, allowing that in broadcast way a soil cannot, for want of quantity of vegetable food, continue to produce annual crops without manure, or perhaps with it; yet, that is no reason why it may not produce them in the hoeing culture if duly performed.

A piece of eleven acres, of a poor, thin, chalky hill, was sown with barley in the common manner after a hoed crop of wheat and produced full five quarters and a half[330] to each acre (reckoning the tithe) which was much more than any land in all the neighborhood yielded in the same year. This, even though some of the neighborhood was so rich that one acre was worth three acres of this land. No man living can remember that ever this produced above half such a crop before, even when the best of the common management has been bestowed upon it.

A field that is a sort of heath-ground used to bring such poor crops of corn, that heretofore the person carried away a whole crop of oats from it believing it had been only his tithe. The best management that ever they did or could bestow upon it was to let it rest two or three years, and then fallow and dung it and sow it with wheat, next with barley and clover, and then let it rest again. I cannot hear of any good crop that it ever produced by this or any of their other methods. It was still reckoned so poor, that nobody cared to rent it. They said dung and labor were thrown away upon it. After two sown crops of black oats had been taken off it, the last of which was scarce worth the mowing, it was put into the hoeing management and when three hoed crops had been taken from it, it was sown with barley and brought a very good crop, much better than ever it was known to yield before. And then a good crop of hoed wheat succeeded the barley; and then it was again sown with barley upon the wheat stubble. And that also was better than the barley it used to produce.

Now, all the farmers of the neighborhood affirm that it is impossible but that this must be very rich ground because they have seen it produce six crops in six years without dung or fallow, and never one of them failed. But, alas! This different reputation they give to the land does not at all belong to it, but to the farmer and their different sorts of husbandry. For the nature of it cannot be altered but by that, the crops being all carried off it, and nothing added to supply the substance those crops take from it, except (what Mr. Evelyn calls) the celestial influences, and that these are received by the earth... in proportion to the degrees of its pulverization.

A field was drilled with barley after a hoed crop, and another adjoining to it on the same side of the same poor hill on exactly the same sort of land was drilled with barley also, part of it after the sown crop the same day with the other; there was only this difference in the soil, that the former of these had no manner of compost on it for many years before, and the later was dunged the year before. Yet the previously dunged crop was not near so good as that which followed the hoed crop which had twice the plowing that the former had before drilling and the same hoeings afterwards (each was hoed three times).

A field of about seventeen acres was summer-fallowed and drilled with wheat, and with the hoeing rough a very good crop (except part of it, which being eaten by trespassing sheep in the winter, was somewhat blighted); the Michaelmas after that was taken off, the same field was drilled

[330] One quarter (or pail) is 8 bushels, so the barley yielded 50 bushels per acre. Using Dr. Jackson's formulas, it is as if Tull added about 70 lbs of nitrogen per acre. While he probably did not increase soil nitrogen that much, the explanation for higher yields lies in fewer plants consuming the same amount of food. Tull likely added at least 14.28 lbs per acre by tillage alone. Any addition of manure, or any native nitrogen would easily account for the difference when there are only 25% of the plants on the field as there would be in Dr. Jackson's experiments: it is as if there is more nitrogen because there is 25% as many plants on the field: with the plants able to forage throughout the wide aisles, none of the nitrogen in their pasture goes to waste.—A.B. & M.C.

again with wheat upon the stubble of the former, and hoed: this second crop was a good one, scarce any in the neighborhood better. A piece of wheat adjoining to it, on the very same sort of land (except that this latter was always reckoned better, being thicker in mould above the chalk, sown at the same time on dunged fallows, and the ground always dunged once in three years), yet this crop failed to become much, as to be judged by some farmers, not to exceed the tithe of the other.

The hoed field has received no dung or manure for many years past because it lies out of reach for carrying of cart-dung, and no sheep are kept on my farm.

Many reasons why Tullians do not keep sheep, many reasons why Virgilians require sheep, and other differences between the old and new husbandries, and why the new husbandry improves upon the old

The reasons why I keep no sheep are many. I have no common, nor downs, nor pasture, nor meadow to keep sheep upon, and sanfoin is unfit for pasturing sheep. So if I kept a flock I should be obliged to till with horses only, which (according to the rules whereby our servants, at present, are pleased to govern us) would cost me one full rent more than the same tillage done by oxen. The profit of pastured sheep depends much upon the owner's skill in managing them, in buying and selling them at proper times, and in many other circumstances; it is a trade that I am not a master of, nor can I have it well done by a deputy.

I find it very difficult to preserve my corn from being spoiled by neighboring sheep, but if I had a flock of my own, it would be more difficult (even besides the trouble and continual quarrels with neighbors about damages done and received). My sheep would be as detrimental to me as they are profitable to others.

But the Virgilian cannot do much without sheep. The urine of a sheep is a great pulveriser of the soil. But in the hoeing husbandry, I know, by many years experience, there is no necessity of a flock of sheep as there is not (in such a farm as mine, managed by such an occupier as I am) a convenience of keeping a flock.

The low price of wool in Britain shows that more sheep are kept here than are for the public benefit; the too great plenty of wool being contrary to that of corn, because foreign countries buy our wool to supply their manufactures in prejudice to our own. And, as the French have none of those statues which we do, the consequence of which enhances the price of our labor to double and in some works to quadruple of theirs, they can afford to pay above double the price for wool that our clothiers can, and yet undersell our merchants of cloth in foreign markets. And the more foreigners have from us, the more will they stock those markets with their cloth. We are apt to have too much wool, as appears by the act for burying bodies in woolen: the living are not sufficient to consume it, and thus we oblige the dead to wear it.

Equivocus, in his Essay for April, p. 17, affirms that I say in my Essay, "that even the dung and urine of sheep are of no use in husbandry," but if the reader cannot find that I have said so, he will be satisfied of the want of veracity Equivocus is guilty of here, as well as in his other false quotations.

Is it not very unfair of Equivocus to represent the farmer's opinion of the odds, as if it were mine, when in the same paragraph I contradict the farmer's opinion? That in my account, I have not exaggerated the odds of those different crops, two of the noble peers, who Equivocus has had the presumption to name (in p. 64, of his Introduction to April), just before harvest, could with justice vindicate me from the false imputation he would maliciously cast upon me relating that which he has falsely quoted.

Those two crops grew within two or three horses' length of one another, both on hill ground; mine was formerly a sheep-down, and the other a cow-down, and to this day retains the name of Cow-Down-Hill: the poor crop had not too much dung, nor was it a very dry summer, which I mention in answer to the questions of Equivocus.

I could give many more instances of the same kind, where hoed crops and sown crops have succeeded better after hoed crops than after sown crops, and never yet have seen the contrary; and therefore am convinced, that the hoeing (if it be duly performed) enriches the soil more than dung and fallows, and leaves the land in a much better condition for a succeeding crop. The reason I take to be very obvious. The artificial pasture of plants is made increased by pulverization only; and there is nothing else in our power to enrich our ground, but to pulverize it, and keep it from being exhausted by vegetables (superinductions of earth are an addition of more ground, or changing it, and is more properly purchasing than cultivating).

This is more especially meant of Virgilian fallows, and a moderate quantity of common dung or the fold: and there may be such a poor sand, or other barrenish soil, so subject to constipation in the winter, as to require dung when planted with wheat, there being no general rule without exceptions. And it is impossible for me to know the number of these exceptions. Well it is for the hoer whose land is of such a kind that he can keep it without dung by hoeing; for when he has no fold, plows his ground with oxen, and plants it mostly with wheat (the straw whereof being for other uses) he can make but very little dung.

I have given reasons for this my opinion; and as far as the authority of Equivocus goes, he confirms the first part of it; for in p. 165 of his Essay for August, he gives up the necessity of dung, after all the stir and stench he has made of it, and says, "that fallowing twice, and sowing with turnips, improve land more than dung." And I believe it will appear upon full trials, that our hoeings, duly and frequently performed, may improve more than twice fallowing: because by hoeing the land is fallowed, and many times iterated every year, and if our plants are only a bare competent number, they may exhaust the land less than a crop of sown turnips. All experienced husbandmen (I do not mean such as have practiced none but Virgilian) will allow, that a Virgilian fallow (which Equivocus, in p. 124-125 of his Essay for July relates) is a very mean improver of the land. He here affirms it for a "well-known truth in husbandry, that wheat should never be sown but upon ground which has been once or twice ploughed, and has lain fallow for a whole summer." Indeed the land lying still one summer might not be much exhausted by the wheat sown therein, without once or twice plowing; for it would produce none, or very little.

These two are all we have in our power, for pulverizing includes an exposure to the atmosphere, without which, I think, it cannot be reduced to particles minute enough or have their superficies so impregnated as to become a fertile pasture for plants. The experiment related by Mr. Evelyn of artificial pulverization seems to prove such an exposure necessary as also the frequent turning (or incessantly agitating) that fine dust for a year before the barren exhausted earth was made rich and prolific: for besides the benefit of pulverization and impregnation, land I more enriched in proportion to the time of exposure, during which it is free from exhaustion, and continually receiving from the atmosphere; therefore frequent turning and exposure are both contained in the words pulverize and not exhaust; and to comply with the latter, we should endeavor that our land may be never exhausted by any other plants than by those we would propagate, and by no more of them neither than what are necessary for producing a reasonable crop. This, upon full trial we find a very small number in comparison to those that are commonly sown. And then, if the supply from the atmosphere by help of the pulverization exceeds the exhaustion, the land will become richer, though constant crops are produced of the same species (as in the

vineyards) and the soil of these are so much improved by the usual pulverization that after producing good annual crops without dung until age has killed the vines, they leave the soil better than they found it and better than contiguous land of the same sort kept in arable-field culture.

By pulverization are meant all the benefits of it that accrue to the pasture of plants, and by exhaustion, all the injuries that can be done to that pasture, except burning. And as the benefits of pulverization visibly continue for several years, so do the injuries of exhaustion (which appear by the ends of some of my rows that have been cleansed of weeds in their partitions by the hand-hoe, and the other ends of the same rows not cleansed – the difference is visible in the color of the wheat in the third and fourth fallowing crops, equally managed). And this is no more to be wondered at than that two unequal sums, being equally increased or diminished should remain unequal until an addition to the lesser, or a subtraction from the greater is made. Which, in case of the soil, must be either by greater pulverization or a lesser exhaustion.

Equivocus, in the last-mentioned page 125, relates that an exposure of the earth to the sun all the summer would rather enervate and impoverish than enrich an extraordinarily fine loamy land, or mouldy ground; but as it appears throughout his whole treatise, that he is most fond of false positions wherever he finds them, and when he does not find them, he makes them out of his own brain. He must excuse me for suspecting this position to be of the latter sort, unless he can produce some other author for it. I am sure it is contrary to all the experience I ever saw in any sort of land, or heard of before on this sort of land.

Their one year's tillage, which is but two plowings before seed-time, commonly makes but little dust and that which it does make, has but a short time to lie exposed for impregnation. And, after the wheat is sown, the land lies unmoved for near twelve months, all the while gradually losing its pasture by subsiding and by being continually exhausted in feeding a triple stock of wheat-plants, and a stock of weeds, which are sometimes a greater stock. This puts the Virgilians upon a necessity of using dung, which is, at best, but a succedaneum of the hoe. For it depends chiefly on the weather, and other accidents, whether it may prove sufficient by fermentation to pulverize in the spring, or not; and it is a question whether it will equal two additional hoeings, or but one... Though, as I have computed it, one dunging costs the price of one hundred hoeings.

It is possible, perhaps, to pulverize the ground with a pen, and they seem to act almost as oddly, when, at such a vast expense, instead of a hoe, they make use of a t—[331] , to help them in their pulverization.

When they have done all they can, the pasture they raise is generally too little for the stock that is to be maintained upon it and much the greatest part of the wheat-plants are starved. From twenty gallons of seed they sow on an acre they receive commonly no more than twenty bushels of wheat in their crop, which is but an increase of eight grains for one. Now, considering how many grains there are in one good ear, and how many ears are on one plant, we find that in ten that lives till harvest, even when there has not been frost in the winter sufficient to kill any of them (or, if we count the number of plants that come up on a certain measure of ground, and count them again in the spring, and likewise at harvest), we shall be satisfied, that most, or all of the plants that are missing could die by no other accident than want of nourishment.

And they have oftener less than sixteen bushels and this harvest[332]. In 1735, a substantial experienced farmer had no more than four bushels of wheat to an acre throughout a field of forty

[331] We will never know what this was intended to say. Obscured by the previous publishers, never amended or corrected by Tull, it is a mystery. —A.B. & M.C.

acres, being robbed by poppies; and I have heard of a crop that has amounted to no more than two bushels to an acre, and some crops less, though dunged and fallowed. Taking the common sown crops of wheat one with another, they are thought not to amount to sixteen bushels to an acre.

They are obliged to sow this great quantity of seed to the end that the wheat, by the great number of plants, may be the better able to contend with the weeds. And yet, too often at harvest, we see a great crop of weeds, and very little wheat among them. Therefore, this pasture being insufficient to maintain the present crop, without starving the greatest part of its plants, is likely to be less able to maintain a subsequent crop, than that pasture which is not so much exhausted.

When their crop of wheat is much less than ours, their vacancies (if computed altogether) may be greater than those of our partitions and intervals; theirs, by being irregular, serve chiefly for the protection of weeds for they cannot be ploughed out, without destroying the corn, any more than cannons firing at a breach, whereon both sides are contending, can kill enemies and not friends.

Their plants stand on the ground in a confused manner, like a rabble; ours like a disciplined army: we make the most of our ground, for we can, if we please, cleanse the partitions with a hand-hoe and, for the rest, if the soil be deep enough to be drilled on the level in triple rows with partitions at six inches and the intervals five feet, five parts in six of the whole field may be pulverized every year, and at proper times all round the year.

The partitions being one-sixth part for the crop to stand on, and to be nourished in the winter, one-sixth part being well pulverized, may be sufficient to nourish it from thence till harvest; the remainder, being two-thirds of the whole, may be kept unexhausted, the one-third for one year, and the other third of it two years... all are kept open for the reception of the benefits descending from above. So that, during so long a time while the sowed land is shut against them, every summer, except the little time in which it is fallowed, once in three years and a little, perhaps, while they plough it for barley in the winter (which is a season seldom proper for pulverizing the ground). This may be done though the roots of a competent number of plants run through the whole, in this manner hereinbefore explained.

Their land must have been exhausted as well by those supernumerary plants of wheat while they lived, as by those that remain for the crop, and by the weeds. Our land must be much less exhausted, when it has never above one-third part of the wheat-plants to nourish that they have, and generally no weeds; so that our hoed land having much more vegetable pasture made, and continually renewed to so much a less stock of plants, there must be left, by every crop, a soil in a much better condition than theirs is left in by any one of their sown crops, even though our crops of corn at harvest be better than theirs.

They object against us, saying that sometimes the hoeing makes wheat too strong and gross, whereby it becomes more liable to the blacks (or blight of insects); but this is the fault of the hoer, for he may choose whether he will make it too strong, because he may apply his hoeings at proper times only and apportion the nourishment to the number and bulk of his plants. However, by this objection they allow, that the hoe can give nourishment enough and therefore they cannot maintain that there is a necessity of dung in the hoeing husbandry; and that, if our crops of wheat should happen to suffer by being too strong, our loss will be less than theirs is too strong since it will cost them nine times our expense to make it so.

[332] Perhaps this is where Dr. Warkentin got his mysterious 16 bushels per acre yield? We can think of no other place in this or other volumes of Tull. It begs too many questions to ask, and we will not even attempt one for Dr. Warkentin, though we desire to know why he attributes yields from Virgilian expectations to Tull. —A.B. & M.C.

A second objection is, that as hoeing makes poor land rich enough to bear good crops of wheat for several years successively, the same must needs make very good land become too rich for wheat. I answer, that if possibly it should so happen, there are two remedies to be used in such a case; the one is to plant it with beans, or some other vegetable, which cannot be over nourished (such as turnips, carrots, cabbages, and such like, which are excellent food for fatting of cattle), or else they may make use of the other infallible remedy, when that rich land, by producing crops every year in the hoeing husbandry, is grown to vigorous and rested, they may soon take down its mettle by sowing it a few years in their old husbandry, which will fill it up again with a new stock of weeds to suck it out of heart, and exhaust its vigor faster than their dung can restore.

There is a third objection, and that is, that the benefit of some ground is lost where the hoe-plough turns at each end of the lands; but this cannot be much, if any, damage; because about four square perches to a statue acre is sufficient for this purpose, and that, at the rate of ten shillings rent, comes to but three pence. Though admittedly this varies, according to whether the land is longer or shorter, but supposing the most to be eight perches, that is but sixpence per acre, it is not lost altogether: for whether it be of natural or artificial grass, the hoe-plough in turning on it, will scratch it and leave some earth on it that will enrich it so much that it may be worth its rent for baiting of horses or oxen upon it. And besides, these ends are commonly near quick-hedges or trees, which do so exhaust it that when no cattle come there to manure it, it is not worth the labor of plowing it.

Tools of the Horse-Hoeing Husbandry

It is strange that no author should have written fully on the fabrication of ploughs! People of the greatest learning have spent their time in contriving instruments to measure the immense distance of the stars, and in finding out the dimensions—even the weight—of the planets; they think it more suitable to study the art of ploughing the sea with ships than the tilling the land with ploughs. They bestow the utmost of their skill, learnedly, to pervert the natural use of all the elements for a destruction of their own species by the bloody art of war: some waste their whole lives in studying how to arm death with new engines of horror, and inventing an infinite variety of slaughter, and think it beneath people of learning (who are the only people capable of doing it) to employ their learned labours in the invention of new (or even improving the old) instruments for the increasing of bread!

—Jethro Tull

CHAPTER TWENTY: OF PLOWS

PLOWS

How plows were invented: by the imitation of animals. Plows were invented early in human civilization; the process of agriculture cultivated the human species. Humans noticed and then studied the effects on seeds and plants of animals performing tillage-like actions

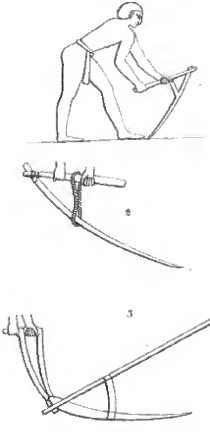
By what means plows and tillage came to be invented is uncertain, therefore we are at liberty to guess.[333] It seems most probable that it was (like most other inventions) found out by accident,

[333] Chandos Hoskyns in his *Short Inquiry into the History of Agriculture* (1849) investigated this point exactly. We now quote from his book, beginning on page 26:

To understand its form and origin, it is necessary to bear in mind that the Plough was undoubtedly a substituted instrument, intended to accomplish more expeditiously, and on a larger scale, by means of animal draught, that which would in the first instance be the work of a simple tool used by the hand. In this country we should at once pronounce that tool to be the Spade; but if we go no further off than the shores of Spain and Portugal, we shall be induced to pause before we award the palm of antiquity to that implement. The city of Cadiz was colonised, at a very remote period, from the eastern shore of the Mediterranean, by the Phoanicians. No district of western Europe claims so high a pedigree, in regard to the useful arts, as the coast of the Peninsula reaching from Vigo to the Straits of Gibraltar: and there we find that the implement of single-handed cultivation is not the spade, but what we should describe as a sort of Hoe, with a very long blade. With this the workman cleaves the ground, using it as we do the pickaxe, dragging towards him the broken soil, as he stands on which, the treading of his feet helps, in a dry climate, to break the clods as they are torn away from the 'land side,' as the farmer would call it. It is obvious that this mode of cultivation would not suit a moist climate like our own, as the treading would injure instead of assisting the work of comminution. The Portuguese, who got it through the Phoenicians, from the East, have in turn carried it to their own colonies, where it may be seen, in Madeira, the Brazils, the West Indies, and even at the settlement of Macao in China, as the common instrument of tillage, just as the spade is with us. I have often been surprised, when watching its use both in Portugal and Madeira, at the efficiency with which it performs its task, tearing up the soil to the depth of two and even three feet. It is an instrument with one long blade, but bent to a more acute angle with the handle than either of the blades of the pickaxe, and sometimes connected with it by a crossbar of wood or iron, reminding one of the capital letter A, with one leg shorter than the other: a comparison worth bearing in mind for reasons that will presently appear.

In the Egyptian paintings and hieroglyphics, in the Museum, this object constantly occurs both by itself and in the hand of the workman. Now let us imagine him, tired of the slow process of tearing up the soil by hand with this implement, to conceive the idea of yoking a pair of oxen (for horses were never used in ancient agriculture) to the end of the handle, and making them drag it along the field, tearing up a sort of furrow as it goes; he himself following and holding it at the point where the blade and the handle join. The oxen would, in this, only be doing more quickly and on a larger scale what the workman had been doing more slowly, though with more care and finish. The instrument would

tear up the soil as it went, and throw it in irregular lumps on both sides; the workman, however, would desire that it should throw the soil on one side only, in order to leave a clear trench to receive the next furrow-slice in coming back; he would soon find it convenient, therefore, to give a twist to the blade of the instrument, so as to make it cast out the furrow-slice on one side, obliquely, which would have the further advantage of presenting an edge instead of its flat side to the soil, as it went along. Now picture the yoke of oxen pulling at the end of the long handle, the man holding the instrument by the apex (extended out a little to give him more leverage and command for steadying it), the blade twisted obliquely, so as to cut forwards and press out the soil sideways, and the little cross-bar sharpened so as to cut the soil in advance, instead of being an impediment, and we have at once the rude elementary form of the Egyptian plough, the same instrument used by the Lycian peasant to this very time, and containing the skeleton of the machine, from the first that ever was invented, down to the last "new and improved" Scotch or English plough of the present day. By the inversion of the implement, the long handle of the Sarcle (the name given to it by the Romans) becomes the "beam" of the plough, the blade turns into the 'share,' the cross bar into the "coulter," and, by the elongation at the point, as before noticed, to give steadiness in holding, we have the one "stilt" or "tail," well known in the forms of the Greek and Roman plough, though the double stilt is also to be seen, and seems to be quite as ancient as the use of only one. The figures in the adjoined sketches are taken from Rossellini's Monumenti dell' Egitto (fol., 1832), in the British Museum.



Hoskyns goes on to show the connection between this letter / hieroglyphic and the origin of the words for government, various legal terms for property ownership and use, the influence of the plow on the development of religion and civilization, and eventually its perfection by Jethro Tull.

His book is entertaining and educational, and follows also the development of yeasted bread and its influence on religion and government, and the modern popularity of Indian corn. He rightly argues for coarse bread: whole grains provide more nutrition than polished grains, and adequate nutrition to feed hard working people and animals. Polished grains only provide energy, without much nutrition.

He urges the reader to trust to the development of civilization, looking at the simultaneous cultivation of the soil and the cultivation of humanity, and it's inevitable results:

The slow response of nature to the questionings of an individual mind, the small and protracted experiments for which a single life is barely sufficient, in an art opening up such infinite variety of circumstance and condition, are multiplied a thousand fold by the involuntary combination of a host of cotemporary searchers engaged in the same, or in collateral pursuits, and connected by the tie of mutual interest in each others' discoveries. The aid of the press, and the increasing facilities for the transmission of its productions, witnessed in our own day, bid fair to dissipate gradually the mist which seems spread over the whole earlier history of Agriculture, when the efforts of each toiler were shrouded from the view of others, by the isolation of his own acres, and the difficulty of combination to a common end. The early struggles of the human race, which have printed the bloody stamp of the sword upon the continuous page of the biography of our species, and have again laid its impress upon the most recent experience of our own generation, have found, at least in our own country, a respite pregnant with happier promise, in the rapid discoveries of science, and advancement of social intercourse, from which it may, perhaps, without presumption, be conceived that the purposes of a beneficent, though inscrutable Wisdom, may be consistent hereafter with a state of peace on earth, founded upon a wider basis than any which the earlier condition of mankind has appeared to present. Should this be indeed presumable, a conclusion cannot fail to suggest itself out of the primeval and long antagonism of the Sword and the Ploughshare, which must place the whole subject of Agriculture before us in a new point of interest, through its relation with the increasing numbers of mankind.

The steady advance of population in this and the other temperate regions of the earth, exhibiting in the case of our own country (after taking the balance of births and deaths), a surplus daily of nearly a thousand fresh mouths demanding sustenance ; the rapid increase of towns, of roads, railroads, and of buildings, all requiring their portion from the surface of the land, have begun to present the somewhat important problem of an increasing occupation of a limited area of space. We are told that in the Chinese empire the effects of this phenomenon are witnessed in a condition of results, of which we have as yet reached no experience, and can form, therefore, but little conception : nor is it reasonable to suppose that any just analogy could be drawn even from a similar state of circumstances here, under such opposite conditions as the comparison would present. Yet, prodigal of space as the soil may seem to us, it has its denned and absolute limit; and the idea, however once remote, must acquire increasing force, that whilst its actual quantity remains fixed, its proportionate area to the numbers it supports is daily diminished at an advancing ratio.

Yet to the improved resources of art we are already indebted for an augmentation of the produce of the soil, in a near proportion to the growing demand, and that not only by the aid of newly-found manures, and a consequent increase of yield, but what is especially observable, by that other and less exhaustible fertilising agent, — the inventive faculty of the human mind, investigating, adapting, arranging, and economising in a thousand ways the means and appliances of the matter submitted to its operation. The abundance of Nature, limited as it may seem, alone, is here united with a principle which renders it perhaps illimitable. At every fresh step the progress of Science presents a bi-fold character,

opening up not only the gifts of the material creation to our hand, but revealing the specific adaptation of our hand to render its resources newly and more compendiously available. And when it is borne in mind that the productions of the earth are the basis of all trade, the source of all wealth, and, (through the interchange of commerce,) the leading cause of the social intercourse of nations, the study of improved Cultivation destined, perhaps, to be coeval with the continued existence of the human race, can be held in no light regard by any mind that has arrived at the perception how intimately blended and indissoluble are the links by which our material wants are connected with every other element and condition of our being, from the lowest to the highest. For if the physical sciences, as we call them,—if those familiar names of Geology, Chemistry, Botany, Physiology, and the whole string of kindred studies, each in a greater or less degree connected with the labours and research of the agriculturist, be indeed but the multiplied titles which we have given to the various but correlative parts of one great machine,—if their separate investigation be after all found concentric to the same end and object—the knowledge of His works and mode of action, who has made nothing in vain, nothing deficient, nothing superfluous, may they not begin to assume to our understanding something beyond what we are accustomed by habit to associate with the name of "physical?" Have they no ultimate purpose or bearing, no mission to mankind beyond the analysis of a soil, the cultivation of a plant, or the filling of a granary or a museum, as "the be-all and the end-all" of human knowledge? Then were the creation that surrounds it but a mockery to the self-conscious mind, that recognising in these objects the mere pabulum of a material and intellectual life, is sensible of an existence and an aim, to which these are still but the subsidiary faculties.

We look around and find ourselves amidst a great and harmonious system whose laws are ever pressing around us: more and more clearly the knowledge breaks upon us, that we are a constituted and essential part of that system, in which, under the guidance of unerring Wisdom, the humblest even of the material parts have each their appointed purpose and connection with the rest, and as the subjects of human labour and intelligence, become pregnant with results which carry on, far beyond our own ephemeral plans and purposes. It is at this point of view that the material and the moral world begin to blend together to our mind and reasoning. Causes and effects which we once regarded as purely physical and temporary, begin to assume a wider aspect, a permanence and moral fixity of purpose, which, when regarded by themselves, we had never attached to them. The sustenance, the comforts, the conveniences of life, achieved by art and science, are no longer the mere utilitarian objects of human ingenuity, nor the matter from which they are struck out, nor the minds that struck them out, things to contemplate independently or for their own sake alone. Physical things, and the sciences which relate to them, begin to he invested with a garment of meaning and of purpose altogether new. The drained morass, the fresh turned fallow, the waving corn-field, the meadow, with its herbage interspersed by flowers, no longer stand separately before us as things of mere labour, utility, or beauty, or our relation with them the accident of a day. 'Day unto day uttereth speech, and night unto night giveth knowledge,'—but that speech and knowledge are not the mere "profane history" of nature. A higher ordinance and appointment, enveloped within their teaching, become gradually but irresistibly revealed, binding and disposing all to work together to the greatest ends, not of the individual only, but of the whole family of man; not of his physical necessities, or intellectual pursuits, alone, but of his whole relation with that Highest Wisdom, whose evidences and attributes are engraven upon the fabric of nature, in characters not of power or knowledge only, but of universal and inexhaustible beneficence.

It is to that unacquaintance with the true character and relations of the material creation commonly witnessed as the result of an imperfect cultivation of our perceptive faculties, that we can alone trace the almost contemptuous indifference under which the wholesome intercourse with nature, presented by agricultural pursuits, was once committed to the rudest and most illiterate of the human community, and the study of subjects consequently neglected, whose submission to our daily wants and attention affords the best evidence of some higher and inherent claim to our

and that the first tillers (or plowers) of the ground were hogs: men in those days having sufficient leisure for speculation observed that when any sort of seed happened to fall on a spot of ground well rooted up by the swine (whose instinct had instructed them to dig in search of their food) it grew and prospered much better than in the whole unbroken turf. This observation must naturally induce rational creatures to the contrivance of some instrument which might imitate (if not exceed) the efforts of brutes in this operation in breaking and dividing the surface of the earth in order to increase and better its product.

That some such accident gave men the first hints of original agriculture may be inferred from the very little (or no) probability of its being invented originally upon arguments that might convince (by just conclusions from ideas of the earth and vegetation) any reasonable people to hope that the effect of increasing the earth's produce should follow the cause of tillage; or, in other words, to answer the question of why the ground should produce more when tilled than when untilled. Therefore, it is very unlikely that men should begin to take pains to till the land without any sort of reason why they should do it. And no such reason could they have, before the invention, as they had afterwards for when they accidentally saw that effect should follow cause, then they were well convinced it did so. [334]

regard. To follow their daily occupation, blind to its chiefest privileges, or merely intent upon its more perishable objects, has been hitherto the misfortune of many, the fault perhaps of some, amongst that class whom the poet of Mantua has memorably designated as "only too happy, did they know their own blessings." Forgetting, or never having considered, that He who made the mind of man can address it without the aid of language, that the whole creation is His book of Symbols, adapted to strike its images direct upon the mind, as on a mirror, and replete with analogies that penetrate through the bodily, to that inward, vision, which we aptly term Re-flection, we are wont to disrobe the earth of every solemnity of character or purpose beyond its mere adaptation to our daily requirements, or to an occasional pictorial effect or poetical similitude. Yet, while we acknowledge and enjoy its material uses, neither can nor ought we to be blind to its moral aspect, as the foundation of that analytical course of inductive Truth, which, rising upward from it, like the Ladder in the vision of the Patriarch, mounts step by step towards that highest knowledge attainable by man, the attributes of his Creator depicted in the works of His hand. Ample indications are not wanting, even in the early dawn of physical research with which our own generation is cotemporary, that in this view of his pursuit, as the noon-day of maturer science advances, the agriculturist may recognise his highest privilege and pleasure; and like the bodily health and repose which come from daily industry, may draw from the intercourse with nature to which his avocation leads him, springs of happiness that outlive the toil they have solaced, following their course in the harmony of natural with revealed Truth, and the love and worship that both alike teach, and claim from the finite towards the Infinite.

Who can say what the daydreams of Tull were? What the daydreams of the first inventor of the plow were? Who can say what the Almighty desires were when human hands first touched the newly tilled soil? We do not dare to presume, but we hope they would have enjoyed those of their student, Hoskyns. —A.B. & M.C.

[334] Of course, Tull here has insight from the development of his own method: he saw the effect, and discerned the cause. He doubts the ability of people to infer the effect of causes they are not familiar with, being beyond the capacity of imagination. Science is limited by imagination, and imagination is, in fact, limited by observation. Even the most absurd dream or surreal art is based upon the observations of reality, composed of elements that originally were seen during the lifetime of the dreamer. Thus, the importance of experiments and observations: by training the mind to

But though this argument that tillage increases the product of the earth "because it does" has been sufficient to continue the practice of tillage ever since; yet it is impossible for the inventors to have had this argument before the invention (if it had been invented by men) and not fortuitously discovered.

Had there ever been better arguments whereon this practice, so useful to mankind, was founded, surely some of all the great and learned authors who have written on the subject would have mentioned them. Philosophers, orators, and poets have treated of it in the same theory by which it was first discovered and by no other: land produces more when tilled, and some seem to say the more it is tilled, the more it produces. It does because it does; not a word is said on the pasture of plants, or anything like it. So that all the ancient writers of agriculture did was only to keep that theory in the same degree of perfection in which the first discoverers received it.

Pigs broke up the ground because they used to find their food there by digging; men till it because they find tillage procures them better food than acorns. These reasons are the same for one and the other.

Early historians are ashamed to have learned so noble a discovery from pigs or other animals (ascribing it instead to the teachings of a goddess)

These writers are ashamed to acknowledge so noble a discovery to be owing to so mean a foundation and make no mention of the true teachers, but attribute the invention to Ceres a goddess of their own making. She, as they pretend, first taught the art of tillage. With this fable they were so well pleased, that they never attempted to improve that art, lest they should derogate from the divinity of Ceres in supposing her invention was imperfect. But swine had practiced the art of turning the soil and so had men long before the fictitious deity of Ceres was invented. [333]

observe all reality has to offer, we overcome this limitation of imagination and the most paranormal phenomenon can become commonly understood, leading to greater insights about deeper mysteries.

Archimedes, the greatest imaginative genius of the ancients, conceived of and used technology that would be disbelieved as paranormal by his contemporaries and successors. Some believed he had the friendship of gods! Yet, though beyond imagination, his works were real. His invention of the laser, and his use of it in warfare is a good example, requiring MIT University to test the feasibility of Archimedes' design to prove its reality: "Ancient Greek and Roman historians recorded that during the siege of Syracuse in 212 BC, Archimedes (a notably smart person) constructed a burning glass to set the Roman warships, anchored within bow and arrow range, afire. The story has been much debated and a number of attempts to recreate it have been made over the ages. While some attempts have apparently been successful, the death ray is oft dismissed as myth...Our goal was not to make a decision on the myth—we just wanted to assess if it was at least possible to achieve in a simple manner, and to have some fun in the process..." (Product Engineering Processes, *Archimedes Death Ray: Idea Feasibility Testing*, October 2005 : http://web.mit.edu/2.009/www/experiments/deathray/10_ArchimedesResult.html) . Indeed, the young students burned a mock Roman ship, bringing the temperature to more than 1000 degrees with bronze mirrors. Other inventions by the great Greek seem equally unreal, but serve to demonstrate the necessity for disciplined collection of data and unbiased observation and questioning of results. —A.B. & M.C.

[333] And ants have been tilling and cultivating the ground even longer. —A.B. & M.C.

First tillage instrument may have been a wooden spade. The plow is nothing but a spade dragged through the soil

With what instrument men first tilled the ground, we don't know exactly; but there may be reasons to believe it was with the spade, and probably a wooden one, and very rough.

For while people lived on acorns there was no use for a smith, such food required no knives for eating it, nor was it worthwhile to make swords to fight for it. And without iron the spade could not be well hewn or shaped; but if it had been such as it is at present, there never was any thing comparable to it for the true use of tillage. Yet the spade could not make that expedition which was necessary when tillage became general in the fields and therefore in time the spade came wholly to be appropriate to the most perfect sort of tillage in the garden. Then the plow supplied the place of the spade it the field; and though it could not (such as it was) till the land near so well, yet it could till ten times more of it, and with less human labor.

Why they did not improve the plow, so that it might also till as well as the spade seems owing to their primitive theory which gave no mathematical reason to show wherein the true method of tillage did consist (in dividing the earth into many parts, to increase its internal surfaces, which is the pasture of plants).

The difference between the operation of the spade and that of the common plow is only this: that the former commonly divides the soil into smaller pieces, and goes deeper.

How easy and natural it is to contrive a plow that may equal the spade, if not exceed it, in going deeper, and cutting the soil into smaller pieces, than the spade commonly does, I leave to the judgment of those who have seen the four-coultered plow. [336]

Early plows had no coulter, coulters are not popular in Italy, Greece or South France: no need for a coulter there because the land was not turfy

The plough described by Virgil had no coulter. Neither do I remember to have seen any coulter in Italy, or the south of France; and as I have been informed, the plows in Greece, and all the east are of much the same fashion. Neither is it practicable to use a coulter in such a plow; because the share does not always cut the bottom of the furrow horizontally, but obliquely; in going one way, it turns off the furrow to the right hand, but coming back, it turns it to the left; therefore, if it had a coulter, it must have been on the wrong side every other furrow; and besides, as the handle (for it has but one) always holds the plough towards one side, with the bottom of the share towards the unplowed land, it would cause the coulter to go much too slow when it went on the furrow side, and it would not touch the ground, when it went on the land side.

Those who say Virgil's plough had two mouldboards make a great mistake, for it had none at all; but the share itself was always going obliquely, and the two ears which were the corners of a piece of wood lying under the share did the office of ground-wrests: this fashion continues to this day in those countries, and in Languedoc.

[336] This is known today as the disk plow, or chisel plow, depending on what kind of coulter is used. —A.B. & M.C.

This sort of plow performs tolerably when the ground is fine, and makes a shift to break up light land; and I could never find any other land there, I am sure, comparable to ours for strength; and it would be next to impossible, to break up such as we in England call strong land with it.

I do not find, that the arable lands about Rome are ever suffered to lie still long enough to come to a turf; but I have observed in the low rich lands in the Calabria that are subject to the invasions of the Turks, that there is some turf, and that these ploughs go over the land two or three times before the turf of it is all broken, though the soil be a very mellow sort of garden-mould. Having no coulters to cut it, they break and tear the turf into little pieces. After this shallow plowing, they can plough deeper afterwards. Having seen this, I thought that this tillage performed by the race of the first teachers of plowing to be no less difficult than harvesting acorns.

English plows are much different because the soil is much different; the need and ways of conquering turf through repeated and improved tillage

The English ploughs are very different from the eastern, as in general the soil is.

These, when well made, cut off the furrow at the bottom horizontally; and therefore, it being as thick on the land side as on the furrow side, the plough cannot break it off from the whole land, at such a thickness (being six times greater than the eastern ploughs have to break off), and must of necessity have a coulter to cut it off; by this means the furrow is turned perfectly whole and no part of the turf of it is broken; and if it lie long without new turning, the grass from the edges will spread and form a new turf (or Swerd) on the other side, which was the bottom of the furrow before turning, but is now become the surface of the earth, and may soon become greener with grass than before plowing; and often the very roots send up new heads to help stock the reversed furrow, the former heads being converted into roots, so that it is doubly clothed and braced on both sides, or as it were, keyed together, firm and solid, almost as a plank; it may be drawn from one side of a field to the other, without breaking, and might possibly be made use of for harrowing or smoothing of fine tilled ground; but not without much time, labor and difficulty can it be made such for itself.

If you plow whole strong turfy furrows crossways, as Virgil directs, and as it is too commonly practiced, the coulter cannot easily cut them, because, being loose underneath, they do not make a sufficient resistance or pressure against its edge, but move before it, and so are apt to be drawn and driven up into heaps, with their surfaces lying all manner of ways, and situate in all manner of postures: so the turf, which is not turned, continuing in the open air, grows on, and with its vigorous roots, holds the earth fast together, and will not suffer the necessary division to be made, which would be, if the turf were rotten, and which is the goal of all tillage, viz. to increase the pasture of plants.

Next, some have vast heavy drags, with great long iron tines in them, and though these huge broken pieces of furrows are looser than before, require keener edges to cut them; yet these drag tines have no edge at all, but are as blunt as the furrows they should cut. These drags draw them sometimes into larger heaps, leaving the under-stratum bare betwixt them, only shaking off some of their mould in tumbling them about, and scratching their surfaces, without reducing them to a moderate fineness, until this ill-broken land has, for above a year, and sometimes longer, entertained plows, cattle, and men, with frequent laborious exercise, for which they are obliged to the one coulter.

If the soil is shallow, it may be broke up with a narrow furrow, which will the sooner be brought in tilth; but if it be a deep soil, the furrows must be proportionally large, or else a part of the

good mould must be left unmoved, and so lost; because a narrow furrow cannot be plowed deep, because the plow will continually flip out the hard land toward the right-hand, unless the rising furrow be of sufficient weight to press the plow towards the left, and keep it in its work: the deeper you plow, the greater weight is required to press it. So, that the deeper your land is, the worse (or in the larger furrows) must it be broke up with one coulter.

Insomuch that if the land is strong (as most deep ground in England is), it is a work of some years to conquer it after it has been rested. And often it happens that the excessive charge of this tillage reduces the profit of rich land below that of much poorer.

This gives an opportunity to deceitful servants of imposing upon their ignorant masters. They plow such deep land with a small shallow furrow, to the end of the turf the furrows may be broken, and made fine the sooner; pretending they will plow it deeper the next time (which is called stirring). But these rogues know very well this cannot be done, and intend no more than that, the plow coming the earlier after the horses, their coats may shine the better, and though there be no crop at harvest, they must have four meals a day, all the year, and extravagant wages at Michaelmas, or at any time of the year, when they may think fit to misbehave themselves.

This sort of land must not be stirred or. plowed the second time in wet weather, for that will cause the grass and weeds to multiply, besides the treading the ground into hard dabs, etc. And in dry weather, the plow will never enter any deeper than it went the first time, the resistance below being so much more than the pressure above, the plow will rise up continually; or if it goes deep enough for the weight of earth to keep it down, another inconvenience will follow, which is that mentioned by Columella,

Quod omnis humus quamvis latissima, tamen inferiorem partem jejuntorem habet, eamque attrahunt excitatae majores Glebe; quo evenit, ut infaecundior material mista pinguiors segetem minus uberem reddat. It spaualts up from below the staple. Hence, the treacherous plowman is secure of an early summer's work, if he can persuade his master to suffer him to fallow the ground with a shallow furrow.

Another way to conquer a strong turf, is, to plow it first with a breast-plow very thin; and when the swerd is rotten, then plow it at the proper depth. But this method is (besides the extraordinary charge of it) liable to other great misfortunes. If the turf be pared up in winter, or early in the spring, there is a chance but the rains cause it to grow stronger than before, instead of its rotting.

And if it is pared later, though dry weather might follow and continue long enough to kill the turf, this loses time and the season of plowing is retarded while all the staple still remains untilled, and before that can be well enough, the year is too far spent for sowing it with wheat (which is the most proper grain for such strong land) and few will have patience to wait, and plow on till another wheat seed time. The dry weather also, which in summer kills the swerd, renders the plowing obnoxious to most of all the evils aforementioned.

Jethro Tull's discussion with a farmer inquiring about the Four Coultered Plow

A farmer inquires concerning the Four Coulter Plow, as in the following dialogue: [337]

FARMER: What must we do then? Must we have recourse to the spade for breaking up our rich, strong, swerdy land?

RESPONSE: If you can procure men to dig it faithfully in pieces, not above two inches and a half thick, at the price of about eight shillings per acre, it would do very well, and answer all the ends of tillage; but though you bargain with them to dig it at that size for three pounds per acre, you will find, upon examination most of the pieces or spits, which are dug out of your sight, to be of twice that thickness. And no great quantities can be this way managed, although the price of corn should answer such an extravagant expense.

FARMER: Since it is so difficult to bring our strong land into tilth, after it has rested, that it cannot be speedily done by a plow without a coulter, or by one with a coulter, in wet weather or dry, nor with a breast-plow, without a certain expense, and an uncertain success, the spade is too chargeable a tillage for the field: it seems to me, upon the whole, that we are losers by this *inaratae gratia terrae*, unless we could contrive some other method of reducing it sooner, and with less charge, into tilth; for I observe, that when we sow it upon the back, the corn and grass (or couch) coming both together, exhaust the ground of so much, that by that time we can (which is about three years) reduce the great lumps to a tolerable fineness; it grows full of grass and weeds (which we call foul) and loses that fertility we expected it should acquire by rest, becoming, in our terms, both out of tilth and out of heart.

RESPONSE: If you know all this to be true, and that, without a coulter you cannot break it up at all; and that, with one coulter you cannot any way cut the furrow small enough, or less than ten inches broad; why do not you cut it with four coulters, which will reduce the same furrow into four equal parts, of two inches and a half each in breadth, and of the depth of the staple, though that should be two spit, or sixteen inches deep.

FARMER: How can that be?

RESPONSE: Every jot as easily as with one coulter. For before the furrow is raised by the share, it lies fast, and makes a sufficient resistance equally against the edges of all the coulters, though after it be raised and loose, it yields and recedes every way, except downwards, so that it cannot be cut by any edge, but such as attacks it perpendicularly from above, as that of the spade does.

FARMER: This seems, to me, reasonable, and having very lately heard talk of this plow I would gladly know more of it.

RESPONSE: The furrow being cut into four parts, has not only four times the superficies on the eight sides, which it would have had on two sides; but it is also more divided crossways, viz. the ground-wrest presses and breaks the lower (or right-hand) quarter; the other three quarters in rising and coming over the earth-board , must make a crooked line about a fourth longer than the straight one they made before moved; therefore, their thinness not being able to hold them together, they are

[337] In a decision of artistic discretion, we have left this largely unedited beyond Cobbett's small improvements, with the intention of maintaining the "color" of the dialogue. It is so full of conversational language that it might change the meaning of the work to bring it into modern slang. —A.B. & M.C.

broken into many more pieces, for want of tenacity to extend to a longer line contrary to a whole furrow, whose great breadth enables it to stretch and extend from a shorter to a longer line, without breaking, and as it is turned off, the parts are drawn together again by the spring of the turf or sword and so remain whole after plowing. Thus the four-coultered plow can divide the soil into above twenty times more parts than the common plow; and sometimes when the earth is of a right temper betwixt wet and dry, the earth-board, in turning the furrows off, will break them into dust, having more superficies than is made by four common plowings; and it is impossible there should be any large pieces amongst it.

Now, what a prodigious advantage must the influences of the atmosphere have upon these small parts, for making a further division of them? Frost, water, drought and nitrous air easily penetrate to their very centers, which cannot in the largest of them be more than one inch and a quarter distant from their superficies. This advantage, with a few subsequent common plowings performed in proper seasons, resolves the earth almost all to a powder. The sword; some being immersed or buried and mixed among so great a proportion of mould, is soon rotten and lost, some of the sword lying loose a top, the earth presently drops out of it, and then the roots are dried up, and die. Thus is the whole staple of the ground brought into perfect tilth in a very short time beyond what the spade ever does in such swerdy land.

FARMER: What sort of weather is best for using this plow?

RESPONSE: Any weather, except if the ground be so dry and hard, that the plow cannot enter it; but it's very proper to be done, when the earth is so wet, that by no means it ought to be plowed with any other plow; for it never can be too moist for this, unless the cattle which draw it be mired: because, though all the cattle should not go in the furrow, yet their treadings are cut so small by the coulters, that the earth is not kept from dissolving, as when turned off whole in common tillage. It is observed, that the incisions made by the coulters on swerdy land will not heal or so close up, but that they will open again by the next plowing, though it be a great while after. A farmer who uses this plow may till in all weathers and all seasons of the year, either in fallowing with this, which is best in wet, or in stirring with the common ones, which must be done in dry weather; and when the ground is broke up with this, it may be stirred in the driest weather that can be; without the danger of tearing (or spaulting) up of the under-stratum along with the staple, because this is all broken before, and then no more can rise with it; as it does to the ruin of the soil, when in common tillage they go deeper the second time than the first; also, if there be a necessity of stirring same sort of land when it is wet, it ought either to be done with this plow, or else with a common one drawn by a single row of cattle treading all in the furrow; for though some land be very fine, yet, when plowed by a double row of cattle in wet weather, it will be made into large pieces by the treading, and perhaps not dissolve again in a long time, therefore it is to be prevented.

FARMER: I perceive this plow lays the foundation for all good husbandry, and there can be no other way to bring land into perfect tilth in so short a time, or with so little expense. And I am convinced that no farmer ought to be without it, who desires to be free from the danger of his land being ever-out of tilth; but I have heard it objected, that it is harder to draw than the common plows: and that its beam being longer, upon account of the four coulters, it lies farther behind, and comes harder after the horses.

RESPONSE: I must confess, there is something in that objection; for this plow being something longer, may be a little the harder draught, and also its weight and strength must bear a proportion to the length of it. But this is small. Increase of the draught would have been a much stronger (if not fatal) objection, had that custom in general, of horses drawing by their tails, as 'tis said to have been formerly in some places; for then, perhaps, a sufficient strength of the horses could

not be applied to the plough. But in countries where traces are in use, every horse of the team may draw the plow equally, and then there will be no other inconvenience, besides the adding one horse, or keeping a stronger team: and he cannot be wife, who would lose the profit of his land, for the odds of sometimes adding a horse to his plow. And I am very certain, that this plow requires a much less strength of cattle to draw it, in moist weather, which is the most proper to use it in, than to draw a common plow I the same ground, and at the same depth, in dry weather; and can seldom be used safely in any other. And the vulgar, who have always a wrong cause ready at hand to apply to everything, impute that draught to the fashion of the plow, which ought to be aided to its going deeper; and this great depth at which 'tis capable of plowing, viz. two spit deep is one extraordinary benefit of it, though it may, on occasion, go as shallow as any.

The draught is not so much increased by adding three coulters, as may be imagined; for when the ground is moist, the incisions are easily made by the edges; and when they are cut small, the furrows rise much more easily upon the share and earth-board, than if whole.

FARMER: If this plow be so beneficial, having so many advantages, and only the two inconveniences, one of requiring a little more strength to draw it, and the other it's being unfit for dry hard ground, I wonder why it is not become more common?

RESPONSE: It has been useful with very great success for these several years last past, but never like to be common, unless it be described in a more Geometrical Manner, than any plow has hitherto been; for the plow-weights find it difficult enough to make a common plow with one coulter to perform as it ought, for want of the necessary rules of their art. It's upon this account that the two-coultered plows are used in few places, though they have been found of excellent use, and have been formerly common: but, alas! When the makers, who by their diligent study and much practice had attained the perfection of their art for want of learning to write their rules mathematically, and show how the mechanical powers were applicable to them, the art was in a manner lost, as the death of those artists; and then the unskillful plow-wrights, destitute of the true rules, were not able to make a two-coultered plow to perform well, and then it was left off. Very lately 'tis revived, since the three and four-coultered ones have been used; from whence some have made a shift top take the rules of placing two coulters into a plow, and they begin to be common again; and, no doubt, will cease again as soon as the rules are forgot.

Need to develop plows through science

It is strange that no author should have written fully of the fabrication of ploughs! Men of the greatest learning have spent their time in contriving instruments to measure the immense distance of the stars, and in finding out the dimensions—even the weight—of the planets; they think it more suitable to study the art of plowing the sea with ships than the tilling the land with ploughs. They bestow the utmost of their skill, learnedly, to pervert the natural use of all the elements for a destruction of their own species by the bloody art of war: some waste their whole lives in studying how to arm death with new engines of horror, and inventing an infinite variety of slaughter and think it beneath men of learning (who are the only men capable of doing it) to employ their learned labors in the invention of new (or even improving the old) instruments for increasing of bread.

The easiest method of perpetuating the use of the many-coultered plows, and other newly-invented instruments of husbandry, is by models, i.e. the things themselves in little, and these may be all portable even in a man's pocket; every part must be fully described, with the true dimensions, and the mathematical reasons on which their contrivance is founded: directions also for using them must

be given at the same time that their manner of making is described. In some the very horses which draw, must be represented, to show the manner of fixing the horses and the traces: cautions against all the errors that may happen by the want of experience in the makers or users must be given.

When this is done, and the rules put into a method, the New Horse Hoeing Husbandry, in all its branches, will be much more easy and certain than the old; because there are no mathematical rules extant in any method; and a man may practice the old random husbandry all his life, without attaining to much certainty in agriculture as may be learned in a few hours from a treatise.

The rules, indeed, require much labor, study, and experience to compose them; but when finished, will be most easy to practice: like the rule for measuring timber, their use is, at first sight, easy to every carpenter, and most artificers who work with wood, but no illiterate person is able to compose those rules, or to measure timber without them.

CHAPTER TWENTY-ONE:
OF SEED DRILLS, DISK PLOWS, MOLDBOARD PLOWS, SPADES, CULTIVATORS, IRRIGATION, STOCK PONDS AND BEAVERS

This chapter is an improvement on Tull's descriptions of his inventions: the descriptions have been made more general to facilitate a better understanding of the purpose and reasoning behind their construction so that they may not only be reproduced, but improved upon

Tull begins his 21st Chapter on the Description of a Four Coultered Plow by the excuse that "to describe all parts of a plow geometrically would require more time and learning than I am master of, therefore leaving that to be done by somebody else, who is better qualified for it, I shall at present attempt little more than what relates to the three added coulters."

His chapter describes the illustrations of the equipment included with the exactness required for a qualified person to construct them.

However, having explained to other farmers various technologies and techniques of the Tullian method, we understand that sometimes such detail serves more to obscure than illuminate the necessary course of action. We have undertaken, perhaps too boldly, to improve on Jethro Tull's writing by explaining, through general illustrations and general descriptions, the equipment required for modern Tullian agriculture, whether undertaken by animal power or tractor power. It serves the reader better to understand the principles behind the technology than the exact placement of pins; the machines are simple, and such descriptions rather serve to make them sound very complicated.

The improvements to the Four Coultered Plow have been amazing, yet it is possible to see Tull's picture and the picture of a modern disk plow and understand its evolution. We have no doubt that the disk plow and seed drill and other equipment necessary to Tullian agriculture will continue to evolve, and we hope to facilitate its evolution by the farmers who would read this by explaining how the machines serve to undertake the necessary functions of the agriculture rather than prescribe a particular machine to undertake it. Technology must serve science, and technology is always evolving. It suffices for the scientist to direct the machinist, and trust the machinist to obey – especially if they are the same person.

In his 22nd Chapter of the Drill Boxes, the theme is continued with only a short introduction: "The drill is the engine that plants our corn and other seeds in rows; it makes the channels, sows the seed into them, and covers them at the same time, with great exactness and expedition. The principle parts of the drill are: the seed box, the hopper, the plow and its harrow. Of these, the seed box is the chief, it measures (or rather numbers) out the seed which it receives from the hopper: it is for this purpose as an artificial hand, which performs the task of delivering out the seed more equally than can be done by a natural hand." He describes that the mechanism that connects the rotation of the wheel of the seed drill to the rate of application of seed, and the means by which a single seed is carried to the ground at a time through a kind of gear (or "mortise") is the most important part of the seed box.

Seed drills are indeed simple enough, until paragraphs of description on construction techniques intimidate the reader to undertake the construction of their own machine. That hoppers should channel seed downward, and ought to funnel them is not complex until it is made so. Neither the amateur nor the expert will find the ancient methods of Tull's construction interesting; such interest lies within the historian, and for the historian a copy of the Second Edition is attached in a separate volume.

Chapter 23 of Tull's edition, without introduction, is about modifications specific to wheat drilling. Tull should trust the farmer to adjust the size of the gear (or mortise) to the smaller size of wheat. The long explanation is unnecessary and confusing. Chapter 24 (concerning the turnip drill, also without introduction) also is unnecessary. The farmer can make adjustments for sizes of seeds, spacing of rows and other necessary modifications without that much instruction. It is common sense.

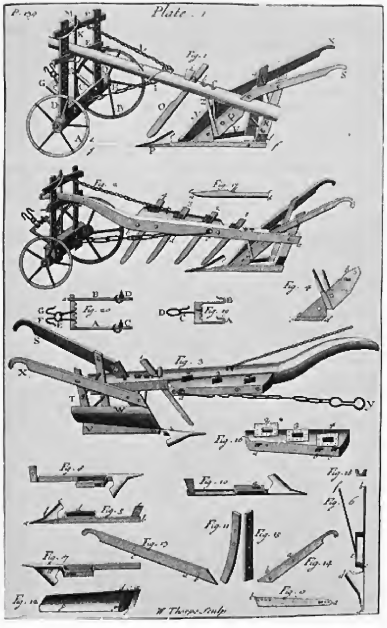
We have added some information on the machines mentioned in this book for the convenience of the reader who might wish to employ them on their farm. These implements are easy enough to construct out of wood, have home-made out of scrap metal, professionally custom-made or, these days, are easily acquired from any number of vendors in whatever width, weight, length or height you'd like, with any number of slight variances.

We have undertaken planting without these magnificent tools. Hand drilling is disastrous without trained, dedicated labor. The laborer will either spill all the seed in a pile on one end or neglect to put the seed in at all. If paid by the hour, they take too many hours to do it. If paid by row, they rush the job and mess it up. If paid a salary or share, they fail for incompetence. If they volunteer out of goodwill and the desire to learn, it is worse. Surprisingly, it is not complicated work (drawing a line in the ground and filling it with seed), but one that requires attention, precision and love, and these qualities sorely lack in anyone not owning the farm itself, no matter how interested they are.

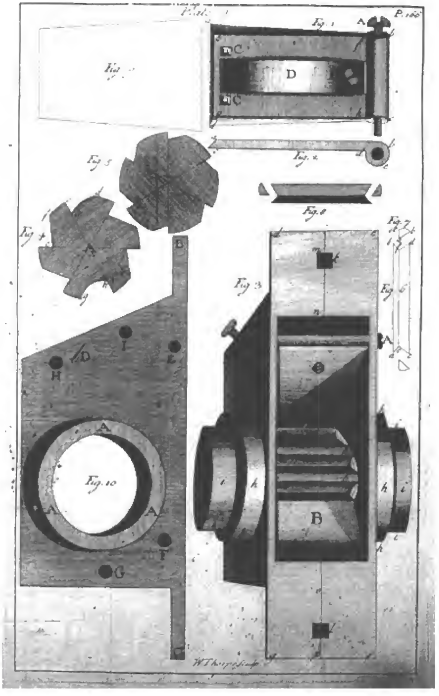
We have, in a pinch, needed to use rototillers instead of disk plows. These have worked tolerably well, except that they form a hardpan after much use. The hard pan is a compacted layer of clay or soil, and must be broken by a chisel plow – a kind of disk plow. Yet, above that, they produce excellently tilled soil.

Several of Tull's illustrations are very educational, and they are included in following pages, discussed afterwards.

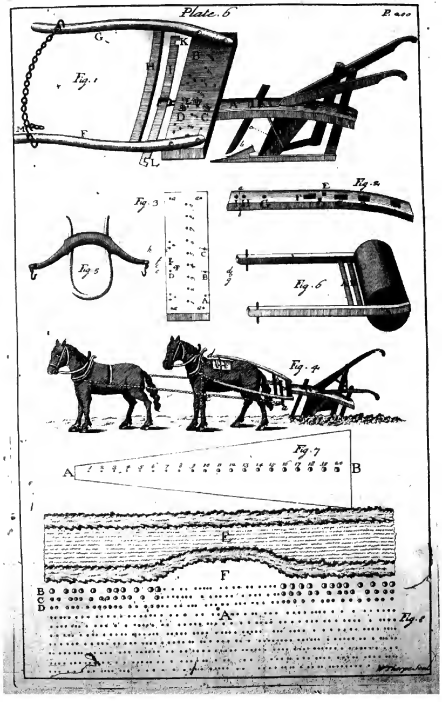
Jethro Tull's Illustration of a Four Coultered Plow



Jethro Tull's Mortise (seed dropping mechanism at the bottom of the seed box, which is attached to the wheels and rotates as the drill travels)



Jethro Tull's Inline Hitch, Etc.



The first illustration, of Tull's four coultered plow, shows the simplicity of the machine: it is a plow, with four coulters. The mouldboard serves primarily to drive the coulters into the ground,

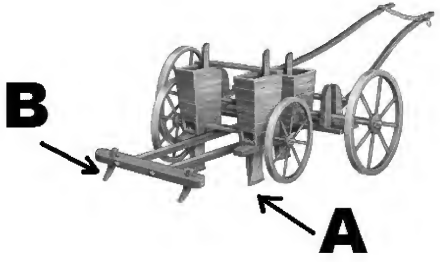
and turn the soil. This is improved by disk coulters, which by their bulge, shatter the soil better than the knife. While Tull's design saves subsequent labor of turning over the soil, the farmer does not always need to turn the soil and these days a second pass is undertaken with a moldboard or cultivator if it is required.

The second is the genius of the seed box, the mortise. The wheel turns around, and a gear-like mechanism exposes to the seed box a notch large enough to fit only one seed: while the notch is very large, an aperture in the bottom of the box exposes to the gear an area large enough for but one seed. In the pictures, the aperture is exaggerated so that it is fully exposing the mortise (above the letter B). This seed is then carefully carried around until it falls below.

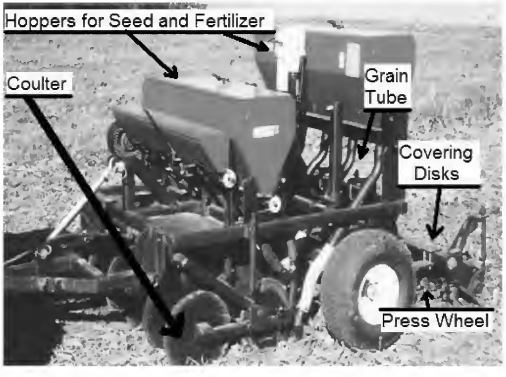
Different numbers of teeth in the gear moderate the density within the row: more notches are tighter seed plantings. Adjustments to the aperture or to the gear can allow for larger or smaller seeds and more or fewer seeds at a time (squashes require 3 seeds at a time, for example). Experimentation can be undertaken with a piece of paper and seeds to identify the proper size of the aperture.

The third illustration, already partially reproduced in previous chapters, also shows Tull's method in action: two horses, hitched in line, pull the plow behind them. Below is seen rows of plants that he observed.

THE SEED DRILL



Above is a picture of what Jethro Tull's 3 row seed drill looked like. Below is a modern example from Kraft Implement (www.kraftimplement.com)



In a seed drill, the axels turn a shaft which has a slot through which seeds can fall to the ground: when the slot is vertically oriented, the seeds fall to the earth from the hopper above. Two hoppers are above: one for seed, the other for fertilizer. An interchangeable panel (measuring only a few square inches) allows a farmer to adjust the size of the hole so that the farmer can regulate how many seeds and of what size fall through at once (and how much fertilizer). Some drills use instead a gear with a spring instead of a hole. Some modern models allow adjustment to the width of the hoppers, so that row width can be customized.

Some modern models operate through the use of a chain drive from the axel, rather than the rotation of the axel itself.

A hopper is a container that is usually shaped like an inverted pyramid or cone; it holds the seeds to be sown.

Modern devices have a coulter to open up the row. Tull lacks these, building in a device into the drop chute itself (A). Modern machines have a grain tube through which seeds flow from the hopper to the row opened in the ground.

In some "no till" drills, the seed is shot into the ground by an air rifle that, surprisingly, does not damage the seed (much). The seed depth can be calibrated by the gun or on the more traditional drills through various levers. On Tull's machine, this is done through some bolts that secure the hoppers and chutes higher or lower as preferred.

To close the row, Tull has some dull harrows (B). These are spaced to knock the soil back into the row opened up by his modified drop chute. Modern drills have covering disks for this.

Tull lacks a roller. In modern drills, a roller is attached by way of a "press wheel." The rolling simply closes the row and assures good soil contact with the seed. That Tull would attach a moldboard to the coulters for convenience and lack a press wheel to rely on a second pass with the roller, and today we rely on a second pass with the moldboard and attach a roller to the seed drill is to environmental considerations.

Was Tull the Inventor of the Seed Drill?

Today the rumor persists that Tull improved upon a Chinese drill, imported from Italy. We believe this is best answered by the author himself, in his Jethro Tull's Supplement, because these lies are as old as he is:

"I am surprised to hear that some gentlemen pretend I brought this instrument from France or Italy when it is well known it had planted two farms with sanfoin before I travelled, which was not until April 1711, being more than 10 years after making and using my drill. The praised Commentator on the Georgic can testify this, he having 27 years ago seen my farm planted in rows by it. I gave one to a neighbor who used it in his fields every year while I was abroad, and it would be strange if I should bring it from countries where it never was...

I took the first hints of my horse hoeing culture from the plowed vineyards near Frontignan and Setts in Languedoc, and after my return to England, having land come into my hands, I improved those hints by observing the same sort of Vineyard Tillage bestowed on potatoes and turnips had the same effect on them as it had on the vines. And then the mentioned row of barley adjoining to the horse-hoed turnips confirmed me in principles, which by arguing from effects to their causes, I had formed to myself and my practice ever since has been a further confirmation to me of the truth of the same principles.

Thus I must acknowledge to owe my principles and practice originally to my travels, as I owe my drill to my organ."

The drill made many enemies. Especially with those whom it put out of work.

The seed drill was invented before aisles and beds, and did not influence the development of aisles and beds

Yet it is insightful to learn that the seed drill came before the aisle and bed system, and that it did not influence the development of the aisle and bed system.

Disk (Coulter) Plow

The disk, or coulter, plow now comes in several forms but the disks themselves (shaped like dinner plates or the athletic "discus," but usually with sharp edges) are usually similar enough between models. They are mounted on a bar so they can be lowered into the soil to a desired depth. The standard line of disks can be modified into a "V" that is either parallel or perpendicular to the movement of the plowing, or doubled to form an X (two V's inverted together). The orientation of the plows will be called important by those who modify them, but in our experience, it does not matter very much which orientation is selected. The disk acts as a knife, cutting down into the soil and pushing it left, right and up while not pushing much down – this results in finely broken soil without much hardpan.

Some disks are modified to turn the soil like mouldboards and have all the disadvantages of mouldboards. Others are modified by having teeth like gears.

The history of the disk coulter is obscure, as no one took special note of its origin or development.

The disks themselves can be loosened by a bolt and rotated as they grow less sharp, or removed and resharpened, or replaced. They are disks because the circular edge cuts the ground better than a straight edge, and the bulge serves to break the soil excellently.

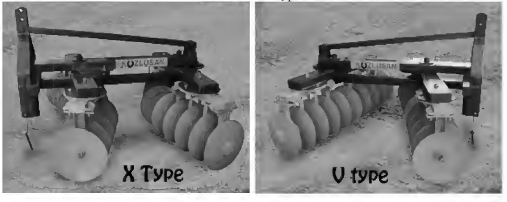


Above: two examples of in-line disk plows.

Below, an ATV is an alternative to the ox or tractor.



Below: X and V types.



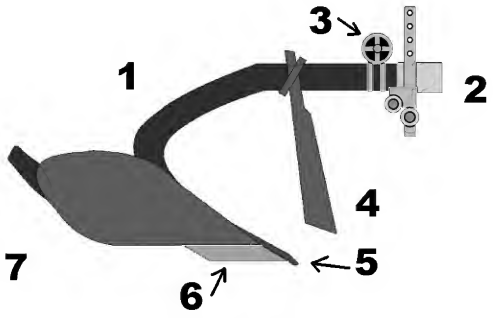
Tull's coultered plow is also found in the modern chisel plow, but after trials with it, we cannot recommend it for any reason. It breaks apart the soil, but it breaks apart the tractor or the animal pulling it as well.

Weights can be added to the disk plow for additional depth capacity (which Tull himself suggests), but larger disks dig deeper with or without weights. Another alternative to weights is mechanically pushing the disks into the soil, either through levers and springs, or through hydraulic pumps.

How far disks are spaced depends on how heavy and hard the soil is, how much it is to be broken, and other considerations of the farmer. 4 inch spacing is not uncommon.

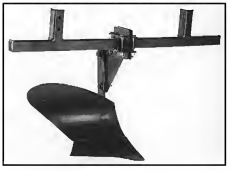
Mouldboard Plows

Tull used mouldboards with the coultered plows for moving soil against or away from beds. Better earthmoving equipment exists today for those using mechanized power, but mouldboards exceed all others when using draft animal labor.



This diagram from the Wikipedia online encyclopedia (we have added the numbers) shows a Jethro Wood Plow (invented in 1819 as the first with interchangeable parts, the first "industrial age" plow), the parts of the mouldboard plow are clearly shown. (1) the frame holds the plow and attaches it to either a (2) three point hitch or (unpictured) a bar which is pulled by a tractor or an animal. A device is sometimes attached (3) to adjust the height, or sometimes the plow is simply lifted by a mechanical hitch. (4) a knife or coulter proceeds the plow to cut the soil in preparation for turning. A knife coulter is shown, but a disk is more popular. (5) The chisel penetrates the soil while the (6) share guides the plow on uncut ground and the (7) mouldboard turns the soil over and pushes it aside. Longer mouldboards are used for clayey soil.

Below left is a picture of a mouldboard without the coulter. Notice that the position on the bar can be adjusted. Sometimes several plows are used together in a "gang" plow. To the right is a picture of the mouldboard in action: turning the soil over and pushing it aside. Complex patterns must be traced on the field to ensure that all the soil is turned without being turned onto the field that has not been turned. This usually involves going around in circles, but if a "reversible" plow is used, the farmer can make one row after another, from one end of the field to the other.





Americans have been improving the mouldboard since Thomas Jefferson applied calculus mathematics to devise less drag on the plow, but all mouldboards, by the action of lifting and turning, necessarily compact the lower levels of the soil and create hardpan.

Whereas the disk plow will not invert the soil, the mouldboard will. Neither will work effectively at fertilizing the soil or destroying weeds except by use in the Tullian method.

Spades and Spading Machines

Spades, or shovels, are the best method of tillage, but they require hand labor to operate and are therefore not only one of the slowest, but the most expensive. It has recently been mechanized, along with the hoe cultivator.

The spading machine improves upon the rotary hoe and its history is related by two of its earliest vendors, Market Farm Implement and Ferrari Tractors.

More properly known as an articulating spader, the spades work like a hand shovel on a crank shaft. Each spade shovel takes a turn entering the soil, so very little horsepower is needed to operate it. It does require a tractor or engine to drive it, as sufficient momentum cannot be gained by the rotation of wheels on the ground to turn the crank shaft.

It is the ideal tillage tool, and requires only a low-horsepower tractor. It can also till damp ground to open it up and dry it out for early spring plantings. These are the two main advantages over the chisel plow.

Like the Chisel Plow, it can be adjusted to till deep or shallow and can till one bed at a time. The Spading Machine is the ideal tillage tool because the spading action completely loosens the soil across the bed and its motion does not compact or smear the soil at the bottom of its travel. Spading machines do not "double dig" and will invert soil with repeated use. The skis control the depth of tillage.



Ferrari Tractors relates that in 1960 Piero Zama formed the Falc Company and by May 1961 began demonstrating his spading machine at the local Agricultural College. Picture 1 shows that first version; see the wheel for depth control, hand shovels, and fork to break up clods. Also notice the location of locating links that create cam action to make spades throw dirt. The spades are not rotated (as in a rototiller), but are thrust into the ground and flicked, imitating human shoveling.

A revised model was demonstrated at an agricultural show in March 1962 where it was recognized for innovation. The machine used 6 spades driven by a single crankshaft powered by a central gearbox receiving its power from the PTO of a 30 HP tractor. The gearbox had several stroking speeds, as is modern practice, each crank arm was 60 degrees out of phase so each spade could penetrate alone, saving power. This first machine was 57" wide and used 6 spades digging 12" deep.



Picture 1

In October 1964 the Falc spader was shown at a major vineyard show in France and in March 1965 Falc spaders were shown at the SIMA show in Paris where it was recognized by the Commission For Technical Research. In 1965 Falc also began exporting spaders; among the first countries were

Holland, Turkey and Israel. Ferrari Tractor C.I.E. in California began importing Falc spaders into USA in 1991.

Far to the west of Faenza, where Zama was working, two Gramegna brothers came up with an idea for a motorized digging machine. Theirs was to be powered with a motor cultivator i.e. a two wheel, walking tractor. Their unit had four shovels with each pair of spades driven by a separate crank shaft driven by its own gear box set side by side and driven by a central PTO from the tractor. A pair of links attaching mid length to each spade arm gave the spades a kicking action to throw dirt to break it against the rear cover as you see in Picture 2



Picture 2

The quality of the work done by this machine was recognized as a big improvement over rototilling. The two wheel model was hard to handle. The Gramegna's started work in 1962 to produce a tractor version. It was introduced in 1963 as a 6 spade model. That early version retained the multiple crankshafts with linked together gearboxes.

The most important feature of design shown here is the location of spade arm's linkage. It is the placement of the attachment point half way between the crank end and spade tip that allows the links to create the motion that keeps topsoil on top and subsoil broken but not intermixed. All spader manufacturers adopted this feature very quickly.

Gramegna began selling their spaders at the Verona Equipment Show in March 1965 and received recognition for invention and innovation at that show. In the years since then Gramegna changed their machine's design to use a single central gearbox to drive a single crankshaft like that used by Falc from the beginning and by all subsequent spader makers. And by the same note Falc adopted the low forward location of the spades arm links to give the kicking action, first used by Gramegna.

Gramegna has continued to innovate offering a unique secondary tiller unit that mounts at rear of their spader to allow a finer breaking of clods to create a shallow seedbed without overworking topsoil. This machine permits you to go from an old compacted pasture to a nursery seedbed in one pass.

In the 1980's Falc began producing a 4.2-meter wide spader (14ft.) that could be mounted in front of a large tractor equipped with a front 3 pt. and front PTO so that a power harrow and seeder could be carried on the rear 3 pt. and driven by the rear PTO. In the 1970's, 80's and 90's other spader manufacturers came into being adopting the same general design but sometimes coming up with unique models to fit special uses.

A couple of interesting examples come from the Tortella Company, who made spader that can be offset to the right so that narrower spader with lower power requirement can still cover tire tracks of wide tractor (Picture 3). Note the offset PTO shaft (the black octagon). The spader in Picture 4 shows a spader capable of working over the top of perennial plants such as artichokes and pineapples.



Picture 3



Picture 4

During the late 1990's and continuing today Celli and Tortella are attempting to produce very wide, 20 plus foot wide spaders to fit California's large scale rice farming operations. Their ability to work wet soils and to incorporate very large quantities of straw make them attractive tools. Celli's approach has been to mount two 10 ft. spaders side by side and drive each of those gearboxes from a third central gearbox. So far that approach has problems with the overheating of the gearboxes. Tortella's version was introduced in the field in California in Fall 2001.

In Picture 5 a standard Falc spader is being used to till wild rice fields while flooded with 10" of water. Here it is the tractor that had to evolve to go where its equipment now could by being equipped with "moon wheels" that allow it to navigate in deep mud and standing water.



Picture 5

Cultivators

Cultivators are basically mounted garden hoes on a frame that is pulled by a tractor or draft animal through the fields. The hoes are spaced so that they go between the rows of crops and designed to penetrate sometimes more, sometimes less deeply. This performs light or shallow hoeing, not the deep hoeing of a disk plow or mouldboard plow.



When the conventional farmer prepares seed beds, they use a variant on the cultivator, and put hoes in formation to pulverize the rows themselves, as shown in the next illustration. The design is the same, but extra cultivators are used in tandem. A standard cultivator simply has one row of hoes, adjustable in width to meet the design of the rows.

Exactly who and when the cultivator was created has been lost to history, but it is an ancient machine. Yet it could never become very successful without precise Tullian rows.

A Tullian system with only one row would need two hoes (one for either side of the row). Two rows would need three hoes. Three rows would need four hoes. Four rows would need five hoes.

Some cultivators have many hoes placed to completely pulverize the soil and undertake shallow tillage (implement pictured below). These resemble improved harrows.



The hoes are sometimes mechanized to rotate in circles along an axle, and then the implement is known as a rotating hoe, rotary hoe or a rototiller. The rotation is usually powered by an engine, because unless the soil is very well broken, the force required to rotate the hoe through the ground using the traction of a wheel drive system would be immense. Ground-driven rototillers have not been invented, but would require comically large ground wheels.



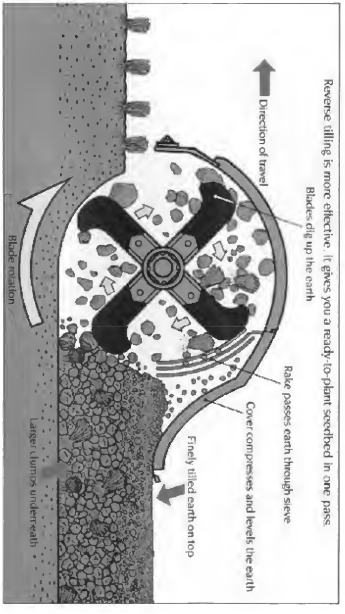
In the above picture of a rototiller, the tines can be seen as having a crook in them. This provides chopping action when spun around. They are held in place by a pin and bolt. It is, quite literally, the action of light or shallow hoeing, mechanically repeated sometimes hundreds of times per minute. This chops the soil very fine. A stick attached to the machine keeps the tines from slipping too deep into the ground, which can be adjusted for what depth is desired.

In a Kubota brand rototiller brochure, the process is diagramed (see following page)

The Kubota rototiller rotates in reverse, pulling up instead of chopping down. It also has a rake to sift out the finer particles so they land on the surface. Many different kinds of rototillers exist. For the microfarm of a few acres, hand-pushed rototillers provide quick, cheap tillage: a unit

can cost less than $1,000, if not equal to, then sometimes even 1/10 the cost of draft animals and equipment.

We used such a rototiller in some urban plots, and successfully serviced 5 acres. Such rototillers are suitable for such agriculture because they are easily transported in the beds of light trucks and even passenger automobiles.


Reverse tilling is more effective. It gives you a ready-to-plant seedbed in one pass.
Blades dig up the earth
Direction of travel
Rake passes earth through sieve
Cover compresses and levels the earth
Finely tilled earth on top
Blade rotation
Large clumps underneath

IRRIGATION

Introduction to irrigation

Irrigation is the artificial application to or the reduction of water in the soil. Besides providing water needs in dry climates and draining water off of wet soils, irrigation also is sometimes used in the protection of plants against frost (when a frost threatens a valuable fruit crop, water is sprayed onto the plants. As the water freezes, it releases warmth that protects the plant from cold damage), and in the suppression of weeds in rice, bog and other production.

The practices of irrigation were likely inspired by nature as early humans observed the cyclical flooding and draining of rivers and lakes, or the activities of dam-building beaver (not all beaver constructed dams: according to the naturalist Enos Mills, it is a learned trait among North American beaver).

Drainage has already been discussed at length in the Chapter of Ridges, so attentions here will be focused on the application of water to soil.

Water must be brought to the field either through the collection of rain water in cisterns or holding ponds, or through the damming of springs, creeks, or rivers into reservoirs, or through pumping ground water from wells. The water is typically moved by canal (a ditch reinforced against the absorption of water through the compaction of its bottom and sides, or the laying of mortar, bricks, tiles or other water-resistant material on the bottom and sides) to the field or an intermediate pond.

Another source of water is ocean water or "bitter" spring water. Before this water is brought to the field, it must be desalinated. The most common way to desalinate is through evaporation and the collection of the resulting water vapor.

Flood irrigation

Flood irrigation, as its name implies, floods a surface of a field with water with the intent (but not usually the result) of an even distribution of that water across the field. To facilitate this somewhat, earthen dams are constructed about the field to hold the water: the field is made into a shallow pond and the water is absorbed into the ground.

Furrow and flooded furrow irrigation

An improvement to flood irrigation is furrow irrigation. In furrow irrigation, water is brought to the field by way of a long, narrow holding pond or canal that runs lengthwise of the field. The pond is elevated above the surface of the field, and is drained into long furrows (shallow ditches) dug along the beds by way of siphons. This reduces the compaction of the ground by the water common in flood irrigation, reduces the erosion of the beds by the water, and, by concentrating the water in ditches near the beds, more efficiently and more permanently increases soil moisture content: higher concentrations of water evaporate less quickly than lower concentrations, and higher concentrations of water will sink deeper under the surface of the soil than lower concentrations.

For furrow irrigation, it is not necessary that beds be raised above the level, but it is common and advisable that they be so raised.

A variant that is advantageous is to construct small levies along the ditch that reduce the rate at which water flows down the ditch: this further reduces erosion and increases water penetration into the soil, increasing the efficiency of the water application. This "flooded furrow" however, requires more work than standard furrows and is not easily mechanized.

Notes on Siphons

Siphons are simple devices to construct. A siphon is a continuous tube that allows liquid to drain from a reservoir through an intermediate point that is higher, or lower, than the reservoir, the flow being driven only by the difference in hydrostatic pressure between the entry port and the exit port. This moves water without any need for pumping. However, for the pressure to move the water towards the exit port, it is necessary that the exit port be lower than the liquid surface in the reservoir.

The way it works is simple. Liquids can rise over the crest of a siphon because gravity pulls on the greater weight of the liquid in the longer outlet leg, allowing the liquid to flow to a lower potential energy state. Siphons can be most easily understood using the conservation of energy: if given the opportunity, liquid will flow downward with gravity to attain a lower energy state. In a siphon, the liquid first rises over a barrier, temporarily increasing its potential energy, so that it can then flow down to a level lower than its starting point, experiencing a net decrease in energy. Thus, once started, a siphon requires no additional energy to keep the liquid flowing up and out of the reservoir. The siphon will pull the liquid out of the reservoir until the level falls below the intake, allowing air or other surrounding gas to break the siphon, or until the outlet of the siphon equals the level of the reservoir, whichever comes first. Energy is conserved because the ultimate drain point is lower than the liquid level of the reservoir.

If the siphon carries the water higher than its origin to begin with (before it can build up momentum), it is necessary to pump the water through the siphon to get it going. This can require as simple a pump as the human mouth, sucking the water through. However, specialized furrow irrigation siphons are designed so that the skilled farmer can fill the tube with water in the reservoir and, quickly, with a trick of the wrist, lay the tube on top of the holding walls of the reservoir: the momentum gained by the movement is enough to prime the siphon and get it going.

Drip and trickle irrigation

Drip irrigation is a term that is misleading. While some drip systems do actually drip, many trickle. Instead of a furrow, a pipe is laid either above, on or beneath the surface of the soil, in the aisles or in the beds, and water is run through the pipe. Holes in the pipe control where and how much water trickles or drips through.

The holes can be improved with subsequent piping to direct the water directly to the base of a plant, if desired.

Drip and trickle irrigation is also possible with half-pipes or reinforced irrigation furrows: in either of these variants, holes are still used to emit the water. The advantage of the half-pipe is its lower cost and reduced technical requirements, the advantage of the reinforced irrigation furrow is its permanence. A major disadvantage to the reinforced furrow is it makes tillage very difficult.

As can be imagined, conducting the water even to the base of individual plants increases water efficiency tremendously. Drip and trickle irrigation is favored in desert areas where evaporation is a major concern.

Rope and bucket irrigation

Water can be brought to the field by buckets attached to ropes, pulleys and wheels to form a continuous loop. The buckets can be "trained" to dump their load into furrows or on plants through the positioning of stakes or poles along their path that force the buckets to tip, or the construction of the water line so that the buckets are forced to tip. Sometimes, holes are put into the bottoms of the buckets and they release their load gradually over their journey. An animal or a person will provide the power to move the rope.

Sprinkler irrigation

Sprinklers are modern devices that improve on the rope and bucket system. They require powerful pumps to operate. They project a stream of water into the air so that the water falls down onto the beds and aisles like rain. In some variants, the water is projected down to the ground from overhead suspension systems. In other variants, the water is misted onto the plants.

Hand or manual irrigation

This least-favorite, most-expensive method of irrigation is undertaken only when absolutely necessary for lack of alternative options. Water is carried by buckets or specialized cans to the plants and applied to the soil.

STOCK PONDS

Improvements to reservoirs to make them accessible and safe for stock use: prevent drowning, reduce shore erosion, include devices for sanitation (including drainage for cleaning, or aquacultural operations that improve the biodiversity of microorganisms)

Before stock may be allowed to access ponds for their thirst, improvements ought to be made for the safety and ease of the animals. The slope of the bottom should not be so severe that an animal who accidently finds themselves in the pond cannot easily climb back out. The depth should not be so deep so that a panicked animal will not drown before finding themselves upon the slope. Vegetation, stones, mortar or other reinforcements should be made near the shore so that the feet of the animals does not erode the pond. Drainage of the pond should be possible for occasional cleaning if disease strikes the herd or flock using it.

The best improvement, however, is the adaptation of the stock pond to function doubly as an aquacultural pond: the animals and plants living in the water will increase the biodiversity of the pond and reduce the risks of disease to the livestock (and sometimes people) who use its waters.

Basic reservoir construction

General guidelines are difficult to offer, as the pond must be adapted to the environment in which it is situated.

As with all reservoirs, the bottom and sides of the pond ought to be reinforced to reduce drainage of the water into the soil. Clay, tiles, mortar, organic matter and other water retardants are typically employed, but sometimes plastic or fabric liners are also used.

Evaporation is also usually a concern. The pond may be partially or entirely covered to reduce evaporation with a building, dome or plastic sheet, and sometimes trees are permitted to grow about it to reduce solar and wind evaporation. Sometimes, they are not permitted to grow within a certain distance of the pond because they pose a risk of predators to the livestock or flock.

The best reservoir practices can be learned from beaver, as demonstrated in the following section.

DOMESTICATION OF BEAVERS FOR IRRIGATION

Notes from the naturalist Enos Mills: Beavers may be employed for pond construction, maintenance and expansion, domesticated for pelt production, and learned from for improved human ponds

Besides various technologies for irrigation, farmers may also rely on domesticated animals to help them in the construction and maintenance of ponds. The naturalist Enos Mills noticed in his authoritative and monumental work, In Beaver World (1913), the beginnings of beaver domestication for agricultural purposes, not for the direct production of their valuable pelts, but for the construction, maintenance and expansion of irrigation and livestock ponds, and reported the first such domestication of the beaver. Though it was, as many domestication efforts are, by accident that human and beaver formed a symbiotic relationship, it is an easy partnership to make and if a farmer is undertaking work in beaver country, it may behoove them to establish and aid a colony upon their land.

Because beaver is still not widely domesticated, and though their lack of popularity does not reduce their utility, we will quote freely from Mills on the history, habits, and the potential for domestication of the beaver as a work animal, and as an animal for the production of pelts, and to learn from these masters of irrigation: there is much to be learned from the beaver in the construction of dams and ditches, and the lumbering of trees. Establishing a partnership with these highly trainable, friendly animals has proven easy, and adapting their domestication beyond the production of pelts to the maintenance of water supplies for aquaculture, livestock or crops is easier. Their importance to a well-balanced ecology aside, beaver have a great potential for the improvement of human agriculture.

In Europe and other places where dam building has not been learned well or at all by beaver, it may be necessary to import colonies of beaver from North America.

Further notes on aquacultural production are made in the chapter on aquaculture.

One September day I saw a number of beaver at work upon a half - finished house. One part of the house had been carried up about two feet above the water, and against this were leaned numerous sticks, which stood upon the top of the foundation just above water-level. After these sticks were arranged, they were covered with turf and mud which the beaver scooped from the

bottom of the pond. In bringing this earth covering up, the beaver invariably came out of the water at a given point, and over a short slide worn on the side of the house climbed up to the height where they were to deposit their load, which was carried in the fore paws. Then they edged round and put the mud-ball upon the house. From this point they descended directly to the water, but when they emerged with the next handful, they came out at the bottom of the slide, and again climbed up it.

The beaver often does a large amount of work in a short time. A small dam may be built up in a few nights, or a number of trees felled, or possibly a long burrow or tunnel clawed in the earth during a brief period. In most cases, however, beaver works of magnitude are monuments of old days, and have required a long time to construct, being probably the work of more than one generation. It is rare for a large dam or canal to be constructed in one season. A thousand feet of dam is the accumulated work of years. An aged beaver may have lived all his life in one locality, born in the house in which his parents were born, and he might rise upon the thousand-foot dam which held his pond and say, "My grandparents half a dozen centuries ago commenced this dam, and I do not know which one of my ancestors completed it."

Although the beaver is a tireless and an effective worker, he does not work unless there is need to do so. Usually his summer is a rambling vacation spent away from home. His longest period of labor is during September and October, when the harvest is gathered and general preparations made for the long winter. Baby beavers take part in the harvest-getting, though probably without accomplishing very much. During most winters he has weeks of routine in the house and ponds with nothing urgent to do except sleep and eat.

He works not only tooth and nail, but tooth and tail. The tail is one of the most conspicuous organs of the beaver. Volumes have been written concerning it. It is nearly flat, is black in color, and is a convenient and much-used appendage. It serves for a rudder, a stool, a prop, a scull, and a signal club. It may be used for a trowel, but I have never seen it so used. It serves one purpose that apparently has not been discussed in print; on a few occasions I have seen a beaver carry a small daub of mud or some sticks clasped between the tail and the belly. It gives this awkward animal increased awkwardness and even an uncouth appearance to see him humped up, with tail tucked between his legs, in order to clasp something between it and his belly.

He is accomplished in the use of arms and hands. With hands he is able to hold sticks and handle them with great dexterity. Like any clawing animal he uses his hands or fore paws, to dig holes or tunnels and to excavate burrows and water-basins. His hind feet are the chief propelling power in swimming, although the tail, which may be turned almost on edge and is capable of diagonal movement, is sometimes brought into play as a scull when the beaver is at his swiftest. In the water beaver move about freely and apparently with the greatest enjoyment. They are delightfully swift and agile swimmers, in decided contrast with their awkward slowness upon the ground. They can swim two hundred yards under water without once coming to the surface, and have the ability to remain under water from five to ten minutes. On one occasion a beaver remained under water longer than eleven minutes, and came to the top none the worse, apparently, for this long period of suspended breathing.

It is in standing erect that the beaver is at his best. In this attitude the awkwardness and the dull appearance of all-fours are absent, and he is a statue of alertness. With feet parallel and in line, tail at right angles to the body and resting horizontally on the ground, and hands held against the breast, he has the happy and childish eagerness of a standing chipmunk, and the alert and capable attitude of an erect and listening grizzly bear.

The beaver is larger than most people imagine. Mature male specimens are about thirty-eight inches in length and weigh about thirty-eight pounds, but occasionally one is found that weighs

seventy or more pounds. Ten mature males which I measured in the Rocky Mountains showed an average length of forty inches, with an average weight of forty-seven pounds. The tails of these ten averaged ten inches in length, four and a half inches in width across the centre, and one inch in thickness. Behind the shoulders the average circumference was twenty-one inches, and around the abdomen twenty-eight. Ten mature females which I measured were only a trifle smaller.

There are twenty teeth; in each jaw there are eight molars and two incisors. The four front teeth of the beaver are large, orange - colored, strong, and have a self-sharpening edge of enamel. The ears are very short and rounded. The sense of smell appears to be the most highly developed of the beaver's senses. Next to this, that of hearing appears to be the most informational. The eyes are weak. The hind feet are large and webbed, and resemble those of a goose. The second claw of each hind foot is double, and is used in combing the fur and in dislodging the parasites from the skin. The fore paws of the beaver are handlike, and have long, strong claws. They are used very much after the fashion in which monkeys use their hands, and serve a number of purposes.

The color of the beaver is a reddish brown, sometimes shading into a very dark brown. Occasional specimens are white or black. The beaver is not a handsome animal, and when in action on the land he is awkward. The black skin which covers his tail appears to be covered with scales; the skin merely has this form and appearance, the scales do not exist. The tail somewhat resembles the end of an oar.

The all-important tools of this workman are his four orange - colored front teeth. These are edge-tools that are adaptable and self-sharpening. They are set in strong jaws and operated by powerful muscles. Thus equipped, he can easily cut wood. These teeth grow with surprising rapidity. If accident befalls them, so that the upper and the lower fail to bear and wear, they will grow by each other and in a short time become of an uncanny length. I have found several dead beaver who had apparently died of starvation; their teeth overlapped with jaws wide open and thus prevented their procuring food. For a time possessed an overgrown tooth that was crescent-shaped and a trifle more than six inches long.

Pounds considered, the beaver is a powerful animal, and over a rough trail will drag objects of twice his own weight or roll a log-section of gigantic size. Up a strong current he will tow an eighty or one-hundred-pound sapling without apparent effort. Three or four have rolled a one-hundred-and-twenty-pound boulder into place in the dam. Commonly he does things at opportune times and in the easiest way. His energy is not wasted in building a dam where one is not needed nor in constructive work in times of high water. He accepts deep water as a matter of fact and constructs dams to make shallow places deep.

Beaver food is largely inner bark of deciduous or broad -leaved trees. Foremost among these trees which they use for food is the aspen, although the cottonwood and willow are eaten almost as freely. The bark of the birch, alder, maple, box-elder, and a number of other trees is also used. Except in times of dire emergency the beaver will not eat the bark of the pine, spruce, or fir tree. It is fortunate that the trees which the beaver fell and use for food or building purposes are water-loving trees, which not only sprout from both stump and root, but grow with exceeding rapidity. Among other lesser foods used are berries, mushrooms, sedge, grass, and the leaves and stalks of a number of plants. In winter dried grass and leaves are sometimes used, and in this season the rootstocks of the pond-lily and the roots of the willow, alder, birch, and other water-loving trees that may be got from the bottom of the pond. Beaver are vegetarians ; they do not eat fish or flesh.

Apparently beaver prefer to cut trees that are less than six inches in diameter, and where slender poles abound it is rare for anything to be cut of more than four inches. But it is not uncommon to see trees felled that are from twelve to fifteen inches in diameter. In my possession are

three beaver-cut stumps each of which has a greater diameter than eighteen inches, the largest being thirty-four inches. The largest beaver-cut stump that I have ever measured was on the Jefferson River in Montana, near the mouth of Pipestone Creek. This was three feet six inches in diameter.

The beaver sits upright with fore paws against the tree, or clasping it ; half squatting on his hind legs, with tail either extending behind as a prop or folded beneath him as a seat, he tilts his head from side to side and makes deep bites into the tree about sixteen inches above the ground. In the overwhelming majority of beaver-cut trees that I have seen, most of the cutting was done from one side, from one seat as it were. Though the notch taken out was rudely done, it was after the fashion of the axe -man. The beaver bites above and below, then, driving his teeth behind the piece thus cut off, will wedge, pry, or pull out the chip. Ofttimes in doing this he appears to use his jaw as a lever. With the aspen, or with other trees equally soft, about one hour is required to gnaw down a four-inch sapling. With one bite he will snip off a limb from half to three quarters of an inch in diameter.

After a tree is felled on land, the limbs are cut off and the trunk is gnawed into sections. The length of these sections appears to depend upon the size of the tree-trunk and also the distance to the water, the number of beaver to assist in its transportation, and the character of the trail. Commonly a six- or eight-inch tree is cut into lengths of about four to six feet. If the tree falls into the water of the pond or the canal, it is, if the limbs are not too long, transported butt foremost to the desired spot in its uncut, untrimmed entirety. Ofttimes with a large tree the trunk is left and only the limbs taken.

The green wood which the beaver uses for his winter's food supply is stored on the bottom of the pond...The green wood stored is almost as heavy as water, and once in the pond it becomes water-logged and sinks in a short time ; however, the first pieces stored are commonly large, heavy chunks, which are forced to the bottom by piling others on top of them. Frequently the first few pieces of the food-pile consist of entire trees, limbs and all. These usually are placed in a rude circle with butts inward and tops outward. This forms an entangling foundation which holds in place the smaller stuff piled thereon.

Most willows by beaver colonies are small and comparatively light. These do not sink readily, are not easily managed, and are rarely used in the bottom of the pile. Commonly, when these light cuttings are gathered into the food-pile, they are laid on top, where numerous up-thrusting limbs entangle and hold them. The foundation and larger portion of the food-pile are formed of heavy pieces of aspen, alder, or some other stream-side tree, which cannot be moved out of place by an ordinary wind or water-current and which quickly sink to the bottom.

Among enemies of this fur-clad fellow are the wolverine, the otter, the lion, the lynx, the coyote, the wolf, and the bear. Hawks and owls occasionally capture a young beaver. Beaver spend much time dressing their fur and bathing, as they are harassed by lice and other parasites. At rare intervals they are afflicted with disease. They live from twelve to fifteen years and sometimes longer. Man is the worst enemy of the beaver.

A thousand trappers unite to tell the same pitiable tale of a trapped beaver's last moments. If the animal has not succeeded in drowning himself or tearing off afoot and escaping, the trapper smashes the beaver's head with his hatchet. The beaver, instead of trying to rend the man with sharp cutting teeth, raises himself and with upraised hand tries to ward off the death-blow. Instead of one blow, a young trapper frequently has to give two or three, but the beaver receives them without a struggle or a sound, and dies while vainly trying to shield his head with both hands.

Justly renowned for his industry, the beaver is a master of the fine art of rest. He has many a vacation and conserves his energies. He keeps his fur clean and his house in a sanitary condition.

Ever in good condition, he is ready at all times for hard work and is capable of efficient work over long periods. He is ready for emergencies.

As animal life goes, that of the beaver stands among the best. His life is full of industry and is rich in repose. He is home-loving and avoids fighting. His lot is cast in poetic places...

One Beaver may well be called the silent workers. No matter how numerous, or crowded, or busy they are, their work goes on without a word and apparently without a sign. Although I have seen them at work scores of times, in the twilight and in the daylight, singly, in pairs, and by the dozens, doing the many kinds of work which beaver perform, yet this work has always gone quietly and without any visible evidences of management. Each one is capable of acting independently. Since the quality of his work improves as the beaver increases his experience, it appears natural and probable that each colony of beaver has a leader who plans and directs the work. I am familiar with a number of instances which strongly indicate leadership. In times of emergency, when an entire colony is forced to emigrate, a beaver and usually an aged one takes the lead, and wherever he goes the others willingly follow.

Whatever may have been the custom of beaver in the past, at present large numbers sometimes cooperate in accomplishing community work. It used to be believed, and possibly it was true, that only the members of a family, or the beaver of one house, united in doing the general work of the colony. It was a common belief that seven beaver inhabited a house ; perhaps eight was the number of the Rocky Mountain region. At the present time the number in a house is from one to thirty.

Beaver have been driven from most of the streams and lake-shores, and now maintain themselves with difficulty in the places which they inhabit. In surviving they probably have had to sacrifice a few old customs and to adopt some new ones, and it is likely that these changes sometimes call for larger houses so as to care for the increased number of beaver which conditions now compel to live in one locality. A number of instances have come under my notice where beaver were driven from their colony either by fire or by the aggressiveness of trappers ; these moved on to other scenes, where they cast their lot with the beaver of another colony, and apparently were received with every welcome. Immediately after the arrival of the immigrants, enlargements were at once commenced, apparently to accommodate the new-comers permanently...

One autumn, while following the Lewis and Clark trail with a pack horse in western Montana, I made camp one evening with a trapper who gave me a young beaver. He was about one month old, and ate twigs and bark as naturally as though he had long eaten them. I named him 'Diver,' and in a short time he was as chummy as a young puppy. Of an evening he played about the camp and often swam in the near-by water. At times he played at dam -building, and frequently displayed his accomplishment of felling wonderful trees that were about the size of a lead pencil. He never failed to come promptly when I whistled for him. At night he crouched near my camp, usually packing himself under the edge of the canvas on which I spread my bedding. Atop the pack on the horse's back he traveled, a ride which he evidently enjoyed. He was never in a hurry to be taken off, and at moving time he was always waiting eagerly to be lifted on. As soon as he noticed me arranging the pack, he came close, and before I was quite ready for him, he rose up, extending his hands in rapid succession beggingly, and with a whining sort of muttering pleaded to be lifted at once to his seat on the pack.

He had a bad fright one evening. About one hour before sundown we had encamped as usual alongside a stream. He entered the water and after swimming about for a time, taking a dozen or so merry dives, he crossed to the opposite side. In plain view, only fifty feet away, I watched him as he busily dug out roots of the Oregon grape and then stopped leisurely to eat them. While he was thus

engaged, a coyote made a dash for him from behind a boulder. Diver dodged, and the coyote missed. Giving a wail like a frightened child, my youngster rolled into the stream and dived. Presently he scrambled out of the water near me and made haste to crawl under my coat-tail behind the log on which I sat.

The nearest beaver pond was a quarter of a mile upstream, yet less than five minutes had elapsed from the time of Diver's cry when two beaver appeared, swimming low and cautiously in the stream before me. A minute later another came in sight from downstream. All circled about, swimming cautiously with heads held low in the water. One scented the place where the coyote had attacked Diver, and waddled out and made a sniffing examination. Another came ashore at the spot where Diver came out to me. Apparently his eyes told him I was a part of the log, but his nose proclaimed danger. After three or four hesitating and ineffectual attempts to retreat, he plucked up courage and rose to full height on hind legs and tail to stare eagerly at me. With head well up and fore paws drooping, he held the gaze for several seconds and then gave a low whistle.

At this, Diver came forth from behind my coat to see what was going on. The old one started forward to meet him, but on arriving a good look at me whirled and made a jumping dive into the water, whacking the surface with his tail as he disappeared. Instantly there followed two or more splashes and a number of tail-whacks upon the water, as though a beaver rescue party were beating a retreat.

At the end of my outing Diver became the pet of two pioneer children on the bank of the Snake River. He followed the children about and romped with them. At three years of age he was shot by a visiting hunter.

My experience with Diver and other beaver pets leads me to believe that beaver are easily domesticated. One morning in northern Idaho, the family with whom I had spent the night took me out to see a beaver colony that was within a stone's throw of their fireplace. Three beaver came out of the water within ten feet of us to eat scraps of bread which the children threw on the grass for them...

The beaver is not often heard. He works in silence. When he pauses from his work, he sits meditatively, like a philosopher. At times, however, when, in traveling, beaver are separated from one another, they give a strange shrill whistle or call. Occasionally this whistle appears to be a call of alarm, suspicion, or warning. Sometimes when alarmed, a young beaver gives a shrill and frightened cry not unlike that of a lost human child. On a few occasions I have heard, while listening near a beaver house in the early summer, something of a subdued concert going on inside, a purring, rhythmic melody. They have a kind of love ditty also. This is a rhythmic murmur and sigh, very appealing, and it seems strangely elemental as it floats across the beaver pond in the twilight.

It is probable that beaver mate for life. All that is known concerning their ways indicates that they are good parents. The young are usually born during the month of April. The number varies from one to eight; probably four is the number most common. A short time before the birth of the youngsters, the mother invites the father to leave, or compels him to do so, or he may go voluntarily, and she has possession of the house or burrow, probably alone, at the time the youngsters are born. Their eyes are open from the beginning, and in less than two weeks they appear in the water accompanied by the mother. Often I have investigated beaver colonies endeavoring to determine the number of youngsters at a birth. Many times there were four of these furry, serious little fellows near the house on a log that was thrust up through the water. At other times from one to eight youngsters sunned themselves on the top of the rude home.

One May, in examining beaver colonies, I saw three sets of youngsters in the Moraine Colony. They numbered three, and two, and five. One mother in another colony proudly exhibited

eight, while still another, who had been harassed all winter by trappers and who lived in a burrow in the bank, could display but one. It is not uncommon for young orphan beavers to be cared for and adopted by another mother beaver. I have notes of three mothers who, with children of their own, at once took charge of orphans left by the death of a neighbor. One June a mother beaver was killed near my camp. Her children escaped. The following evening a new mother, with four children of her own adopted them and moved from her own home, a quarter of a mile distant, to the home of her dead neighbor and there brought all the youngsters up.

Beaver have great fun while growing up. Posted on the edge of the house, they nose and push each other about, ofttimes tumbling one another into the water. In the water they send a thousand merry ripples to the shore, as they race, wrestle, and dive in the pond. They play on the house, in the pond, and in the sunshine and shadows of the trees along the shore.

Beaver are mature the third summer of their lives, and at this time they commonly leave the parental home, pair, and begin life for themselves. There are stories to the effect that the parents of the youthful home-builders accompany the children to new scenes, help them select a building site, and assist in the construction of the new house and dam. After this the parents return home. This probably is occasionally true. Anyway I once saw this program fairly well carried out, and at another time in a limited manner.

The beaver is practical, peaceful, and industrious. He builds a permanent house and keeps it clean and in repair. Beside it he stores food-supply for the long winter. He takes thought for the morrow. These and other commendable characteristics give him a place of honor among the hordes of homeless, hand-to-mouth folk of the wild. During the winter he has but little to do except bathe and eat his two or three meals a day from the food he has stored in the autumn. Towards spring, when his wild neighbors are lean, hungry, and cold, he is fat and comfortable. In the spring he emerges from the house, but then his only work is occasionally to cut a twig for food. In the summer he plays tourist. He visits other colonies, and wanders up and down streams, going miles from home. In the late summer or early autumn he returns, makes repairs, and harvests food for winter.

The beaver is a valuable conservationist, but there are localities in which he cannot be tolerated. Although dead wood is rarely cut by the beaver, many a homesteader has been disturbed by his cutting off and carrying away green fence posts. Recently beaver have returned to a few localities and got themselves into bad repute by felling fruit trees. Occasionally, too, in the West they have lost caste by persistently damming an irrigation-ditch and diverting the water, despite the fact that a court has given both the title and the right to this water to someone else a mile or so down the ditch.

In all logging operations, beaver never fail where there is opportunity to cut trees up-stream and float them down with the current. Tree-cutting is an interesting phase of beaver life. A beaver will go waddling dully from the water to a tree he is about to cut down. All will look about for enemies; one may be wise enough but the majority will not do so to look up-ward to see if the tree about to be felled is entangled at the top. All appear to choose a comfortable place on which to squat or sit while cutting.

Commonly when the tree begins to creak and settle, the beaver who has done the cutting thuds the ground a few times with his tail, and then scampers away, usually going into the water. Sometimes the near-by workers give the thudding signal in advance of the one who is doing the cutting. Now and then no warning signal is given, and the logging beaver occasionally fells his tree upon other workers with a fatal result. As with axe-men, the beaver doing the cutting is on rare occasions caught and killed by the tree which he fells.

Rarely does the beaver give any thought to the direction in which the tree will fall. In a few instances, however, I have seen what appeared to be an effort on the part of the beaver to fell a tree in a given direction. From an uncomfortable place he cut the lowest notch on the side on which he probably wanted the tree to fall. On one of these occasions, the aspen tree selected stood in an almost complete circle of pines. The beaver took pains to cut the first and lowest notch in this tree directly opposite the opening in the pines. I have seen a number of instances of this kind. And he will sometimes leave the windward side of a grove on a windy day, and cut on the leeward, so that the felled trees are not entangled in falling.

Rarely does more than one beaver work at the same time at a tree. In some instances, however, if the tree be large, two or even more beaver will work at once. But after the tree has been felled, ofttimes three or four beaver will unite to roll a large section to the water. In doing this, some may stand with paws against it and push, and others may put their sides or hips against it. On land, as in the water, small limb-covered trees are dragged butt foremost so as to meet the least resistance. Sometimes the beaver drags walking backwards; at other times he is alongside the tree carrying and dragging it forward.

Early explorers say that beaver do most of their work at night. In this they are practically unanimous. However, in Long's Journal, written in 1820, beaver were reported at work in broad day light. A few other early writers have also mentioned this daylight work. They probably work in darkness because that is the safest time for them to be out. During dozens of my visits to secluded localities, localities which had not been visited by man, and certainly not by trappers, found beaver freely at work in broad daylight. I am inclined to think that day work was common during primeval times; and that, although the beaver now do and long have done most of their work at night, in localities where they are not in danger from man, they work freely during daytime.

The beaver is peaceful. Although the males occasionally fight among themselves, the beaver avoids fighting, and plans his life so as to escape without it. Now and then in the water one closes with an otter in a desperate struggle, and when cornered on land one will sometimes turn upon a preying foe with such ferocity and skill that his assailant is glad to retreat. On two occasions I have known a beaver to kill a bobcat.

Beaver are not equally alert. In many cases this difference may be due to a difference in age or experience. Beaver have been caught with scars which show that they have been trapped before, a few even having lost two feet in escaping from traps. On the other hand, skillful trappers have found themselves after repeated trials, unable to catch a single beaver from a populous colony. Sometimes in colonies of this kind, the beaver even audaciously turned the traps upside down or contemptuously covered them with mud.

Nor is the work of all beaver alike. The ditches which one beaver digs, the house one builds, or the dam one makes, may be executed with much greater speed and with more skill than those of a neighboring beaver. Many houses are crude and unshapely masses, many dams haphazard in appearance, while a few canals are crooked and uneven. But the majority do good work, and are quick to take advantage of opportunity, quick to adjust themselves to new conditions, or to use the best means that is available. Beaver probably have made numbers of changes in their manners, habits, and customs, and those changes undoubtedly have enabled them to survive relentless pursuit, and to leave descendants upon the earth.

The industry of the beaver is proverbial, and it is to the credit of any person to have the distinction of working ' like a beaver.' Most people have the idea that the beaver is always at work; not that he necessarily accomplishes much at this work, but that he is always doing something. The fact remains that under normal conditions he works less than half the time, and it is not uncommon

for him to spend a large share of each year in what might be called play. He is physically capable of intense and prolonged application, and, being an intelligent worker, even though he works less than half the time he accomplishes large results...

The beaver has been found in fossil both in Europe and in America. Remnants of the dugout and the teeth of beaver, together with rude stone implements of primitive man, have been found in England. Near Albany, New York, gnawed beaver wood and the remains of a mastodon were dug up from about forty feet below the surface in sediment and river ooze. Fossil beaver were of enormous size.

Coming down to comparatively modern times, the animal as we now know him appears to have been distributed over almost all Asia, Europe, and North America. There was no marked difference in the individuals that inhabited these three continents. The beaver is probably extinct in Europe, but in July, 1903, I found a piece of wood floating in the Seine that had been recently gnawed by a beaver. At this time I was assured that not even a tame beaver could be found in Europe. It is still found in parts of Siberia and Central Asia. That form which inhabits South America is very unlike those in the Northern Hemisphere, and may be called a link between the muskrat and the beaver.

Reference is made to the beaver in ancient Egyptian hieroglyphics, and Herodotus makes repeated mention of it. Pliny also gives a brief account of this animal. In Germany, in 1103, the right of hunting beaver was conferred along with other special hunting privileges; and a bull of Pope Lucius III, in 1182, gave to a monastery all the beaver found within the bounds of its property. A royal edict issued at Berlin in March, 1725, insisted upon the protection of beaver.

Before the white man came, beaver Castor Canadensis were widely distributed over North America, perhaps more widely than any other animal. The beaver population was large, and probably was densest to the southwest of Hudson Bay and around the headwaters of the Missouri and Columbia rivers. Their scantiest population areas in the United States appear to have been southern Florida and the lower Mississippi Valley. This scantiness is attributed by early explorers to the aggressiveness of the alligators.

All the southern half of Mexico appears to have been without a beaver population; but elsewhere over North America, wherever there were deciduous trees and water, and in a few treeless places where there were only water and grass, the beaver were found. Along the thousands of smaller streams throughout North America there was colony after colony, dam after dam, in close succession, as many as three hundred beaver ponds to the mile. Lewis and Clark mention the fact that near the Three Forks, Montana, the streams stretched away in a succession of beaver ponds as far as the eye could reach. The statements made by the early explorers, settlers, and trappers, together with my own observations, which commenced in 1885, and which have extended pretty well over the country from northern Mexico into Alaska, lead to the conclusion that the beaver population of North America at the beginning of the seventeenth century was upwards of one hundred million. The area occupied was approximately six million square miles, and probably two hundred beaver population per square mile would be a conservative number for the general average. In the United States there are a number of counties and more than one hundred streams and lakes named for the beaver ; upwards of fifty post offices are plain Beaver, Beaver Pond, Beaver Meadow, or some other combination that proclaims the former prevalence of this widely distributed builder. The beaver is the national emblematic animal of Canada, and there, too, numerous post-offices, lakes, and streams are named for the beaver.

Beaver skins lured the hunter and trapper over all American wilds. These skins were one of the earliest mediums of exchange among the settlers of North America. For two hundred years they

were one of the most important exports, and for a longer time they were also the chief commodity of trade on the frontier. A beaver skin was not only the standard by which other skins were measured in value, but also the standard of value by which guns, sugar, cattle, hatchets, and clothing were measured. Though freely used by the early settlers for clothing, they were especially valuable as raw material for the manufacture of hats, and for this purpose were largely exported.

From this animal were prepared many remedies which in former times were believed to have high medicinal value. Castoreum was the most popular of these, and from it was compounded the great cure-all. The skin of the beaver was thought to be an excellent preventive of colic and consumption; the fat of the beaver efficient in apoplexy and epilepsy, to stop spasms, and for various afflictions of the nerves. Powdered beaver teeth were often given in soup for the prevention of many diseases. The castoreum of the beaver was considered a most efficient remedy for earache, deafness, headache, and gout, for the restoring of the memory and the cure of insanity. Next in importance to its skin, the beaver was valued for the castoreum it yielded...

The American Fur Company and the Northwestern Fur Company were two large fur-gathering enterprises whose trappers ranged afar and who left their mark in the history and the development of the Northwest. The colossal Astor fortune really had its beginning in the wealth which John Jacob Astor amassed chiefly through the gathering and the sale of beaver skins. Beaver skins are now economically unimportant in commerce, but their value has already led to the establishment of a few beaver farms.

To-day beaver are apparently extinct over the greater portion of the area which they formerly occupied, and are scarce over the remaining in habited area. Scattered colonies are found in the Rocky Mountains and in the mountains of the Pacific Coast, and there are localities in Canada where they are still fairly abundant. In many places in the Grand Canyon of the Colorado they are common. A few are found in Michigan and Maine. Some years ago a few brooks in the Adirondacks were successfully colonized with these useful animals. They have reappeared in Pennsylvania, and there probably are straggling beaver all over the United States which, if protected, would increase.

There is a growing sentiment in favor of allowing the beaver to multiply. In 1877 Missouri passed a law protecting these animals; so did Maine in 1885 and Colorado in 1899. Other States to the total number of twenty-four have also legislated for their protection. The Canadian government has also passed protective laws. A noticeable increase has already occurred in a few localities. Beaver multiply rapidly under protection, as is shown in the National Parks of both Canada and the United States...

In the Bad Lands of Dakota I saw two dams that were made of chunks of coal. This material had caved from a near-by bluff. I have noticed a few that were constructed of cobble-stones. The water-front of these dams was filled and covered with clay, and they were the work of "grass beavers," beaver that subsist chiefly on grass, and that live in localities almost destitute of trees...

It is doubtful if a dam is ever made by felling logs or large trees across the stream. I have, however, seen a few real log dams, but in these the logs were placed parallel to the flow of water. One of these was in the Sawtooth Mountains of Idaho. Here a snow-slide swept several hundred trees down the mountain. This wreckage was piled on the bank of a stream. Beaver in a colony a short distance away accepted this gift of the gods, and of these unwieldy logs built a dam about two hundred feet downstream from where the avalanche had piled the logs. This dam was a massive affair, about forty feet long and eight feet high. It really appeared more like a log jam than a dam, but it served the purpose intended and raised the level of the river so that the water overflowed to one side and spread in a broad sheet against a cliff and through a grove of aspens, which the beaver proceeded to harvest.

The majority of dams are made of slender green poles which are placed lengthwise with the flow for the bottom, and set braced with the end upstream a foot or so higher than the down-stream end. With these there are occasionally used small limby trees. The large end of the tree is placed upstream, and the small bushy end downstream. If in a current these sometimes are weighed down with mud or stones. Short, stout sticks and long, slender poles are deftly mingled in the dam as it rises. The poles overlie, and many completed dams appear as though made of gigantic inclined half-closed shears and compasses of poles. Thus a dam is doubly braced. The weight against it is resisted both by the end-on poles that are parallel to the flow and by those set at an angle to it.

The shape and the material of a dam are dependent on a number of things ; the nature of the place where built, the kind of materials available for its building, the purpose it is intended to serve, and the relation it may have to dams already constructed. Sometimes a small dam will be made that may ultimately become a big one by simply digging a ditch across the stream or basin and piling the excavated material into a dam.

Beaver, like men, are unequal in their skill, both in planning and in doing work, and the work of most beaver falls short of perfection. Errors are not uncommon. More than one colony has commenced a dam apparently without knowing that there was not sufficient available material to complete it. Others have built in the wrong places, and have thus failed to flood the area which they desired to reach or cover with water. Occasionally the difficulties of construction have been too great for the beaver who attempted it, and the dam has been abandoned in an incomplete state. Now and then a weak dam breaks, or a strong one is swept out by a flood.

But why do beaver need or want the pond which the dam forms ? They need it for the purpose of maintaining water of sufficient depth and area to enable them to move about in safety, and to transport their food-supplies with the greatest ease. Above all, the pond is a place of refuge into which the beaver can constantly plunge and have security from his numerous and ever watchful enemies. The house-entrance must be kept water-covered. In the water the beaver is in his element On the land he is a child lost in the wilds. He has extremely short legs and a heavy body. His make-up fits him for movement in the water. He is a graceful swimmer, and in the water can move easily and evade enemies ; while on land he is an awkward lubber, moves slowly, and is easily over-taken. Water of sufficient depth and area, then, is essential to the life and happiness of the beaver. To have this at all times it is necessary, in localities where the supply is at times insufficient, to maintain it by means of dams and ponds.

Deep ponds are needed around the house; shallow ponds with shores in near-by groves facilitate far-away logging. Dams are placed across streams whose waters are to be led away through new channels and made to serve elsewhere in canals or ponds. Dams are made across inclined canals to catch and hold water in them. Streams are beaver's avenues of travel. Along shallow streams in a beaver country it is not uncommon to see an occasional short dam which forms a deep hole, which apparently is maintained as a harbor or place of safety into which traveling beaver may dive and be made safe from pursuit.

Most beaver dams are built on the installment plan. They are the result of growth. The new dam is short and comparatively low. It is enlarged as conditions may require. As the trees in the edge of the pond are harvested, the dam is built higher and longer, so as to flood a larger area ; or as sediment fills the pond, the dam is from time to time raised and lengthened in order to maintain the desired depth of water. Thus it may grow through the years until the possibilities of the locality are exhausted. The dam may then be abandoned. It may be used for a few years or it may be used for a century. A gigantic beaver dam may thus represent the work of several generations of beaver. It often occurs that one or more generations may use a dam and yearly add something to its size. By and by

these beaver may die or emigrate. The old dam remains, falling to ruin in places. Years go by and other beaver come upon the scene. The old dam is then used for the foundation for a new one. The appearance of some old dams indicates that they have been repeatedly used and abandoned.

New dams, being made largely of coarse materials, appear very unlike old ones. Decay, settling, repairs, and other changes come rapidly. The dam is built of poles to-day ; it speedily becomes earthy and is planted by nature to grass, willows, and flowers. On old, large dams it is not uncommon to see old forest-trees. The roots of these entangle the constructive materials, penetrate deeply, and help to anchor securely the entire dam.

In only a few cases are the water-fronts of dams at once plastered or filled in with mud. This is done only where there is a scarcity of water. It is the aim of the beaver to raise the water in the pond to a certain height and there maintain it, the chief purpose of the dam being to regulate the height or the depth of the water. The water, in streaming through new dams, deposits therein quantities of sticks, trash, and sediment, so that in a year or two these choke the holes, almost stop the leakage of the water, and help to solidify the dam. The discharge from dams is regulated by the beaver. In some instances water leaks through a dam in numerous places from bottom to top; in others it seeps through only close to the top ; and in still others the dam is so solid that the water pours over the top in a thin sheet. In some cases, however, instead of the water pouring over the entire length of the dam the beaver force it to pour over in a given stretch at one end or the other, or sometimes through a hole or tunnel. The concentration of the overflow at some one point in the dam is commonly done either for the purpose of using it in transportation or to force the water to outpour on a spot where it will least erode the foundation of the dam. Occasionally beaver compel the water to flow round the end of a dam, which they raise sufficiently high for that purpose. Sometimes they dig a waste-way for the water.

European beaver appear to have barely developed to the dam-building stage. Rarely did they build even a small, unimportant dam. Nor did all the American beaver build dams. At the time the beaver population was most numerous and widely distributed, probably not more than half of them used the dam. However, those not using the dam were living in places where the dam and consequent pond were not needed. Dam-building enormously increased the habitable beaver area. There were, and are, thousands of brooks which each year cease to flow for a period, yet on these brooks are all other beaver requirements except a permanent, sufficient water-supply. By dam-building water is stored for to-morrow, or stream-courses changed, and with the assistance of canals water is diverted to a dry ravine where a colony is established.

The dam is the largest and in many respects the most influential beaver work. Across a stream it is an inviting thoroughfare for the folk of the wild. As soon as a dam is completed, it becomes a wilderness highway. It is used day and night. Across it go bears and lions, rabbits and wolves, mice and porcupines; chipmunks use it for a bridge, birds alight upon it, trout attempt to leap it, and in the evening the graceful deer cast their reflections with the willows in its quiet pond. Across it dash pursuer arid pursued. Upon it take place battles and courtships. Often it is torn by hoof and claw. Death struggles stain it with blood. Many a drama, romantic and picturesque, fierce and wild, is staged upon the beaver dam.

The beaver dam gives new character to the landscape. It frequently alters the course of a stream and changes the topography. It introduces water into the scene. It nourishes new plant life. It brings new birds. It provides a harbor and a home for fish throughout the changing seasons. It seizes sediment and soil from the rushing waters, and it sends water through subterranean ways to form and feed springs which give bloom to terraces below. It is a distributor of the waters; and on days when dark clouds are shaken with heavy thunder, the beaver dam silently breasts, breaks, and delays

the down-rushing flood waters, saves and stores them ; then, through all the rainless days that follow, it slowly releases them.

Most old colonies have many dams and ponds. A dam is sometimes built for the purpose of forcing water back and to one side into a grove that is to be harvested for food. In many cases water flows round the end of a dam, and in making its way back to the main channel is intercepted by another dam, then another; and thus the water from one small brook maintains a cluster or chain of pondlets...

the aged beaver had lifted a small aspen limb out of the water and was squatted on the log, leisurely eating bark. Before many minutes elapsed the other beavers became restless and finally started up the slope in a runway. They traveled slowly in single file and one by one vanished amid the tall sedge. The old beaver slipped noiselessly into the water, and a series of low waves pointed toward the house. It was dark as I stole away in silence for the night, and Mars was gently throbbing in the black water.

This was an old beaver settlement, and the numerous harvests gathered by its inhabitants had long since exhausted the near-by growths of aspen, the bark of which is the favorite food of North American beaver, though the bark of the willow, cottonwood, alder, and birch is also eaten. An examination of the aspen supply, together with the lines of transportation, the runways, canals, and ponds, indicated that this year's harvest would have to be brought a long distance. The place it would come from was an aspen grove far up the slope, about a quarter of a mile distant from the main house, and perhaps a hundred and twenty feet above it. In this grove I cut three notches in the trunks of several trees to enable me to identify them whether in the garnered pile by a house or along the line of transportation to it.

The grounds of this colony occupied several acres on a terraced, moderately steep slope of a mountain moraine. Along one side rushed a swift stream on which the colonists maintained three but little used ponds. On the opposite side were the slope and summit of the moraine. There was a large pond at the bottom, and one or two small ponds, or water-filled basins, dotted each of the five terraces which rose above. The entire grounds were perforated with subterranean passageways or tunnels.

Beaver commonly fill their ponds by damming a brook or a river. But this colony obtained most of its water-supply from springs which poured forth abundantly on the uppermost terrace, where the water was led into one pond and a number of basins. Overflowing from these, it either made a merry little cascade or went to lubricate a slide on the short slopes which led to the ponds on the terrace below. The waters from all terraces were gathered into a large pond at the bottom. This pond measured six hundred feet in circumference. The crooked and almost encircling grass-grown dam was six feet high and four hundred feet long. In its upper edge stood the main house, which was eight feet high and forty feet in circumference. There was also another house on one of the terraces.

After notching the aspens I spent some time exploring the colony grounds and did not return to the marked trees until forty-eight hours had elapsed. Harvest had begun, and one of the largest notched trees had been felled and removed. Its gnawed stump was six inches in diameter and stood fifteen inches high. The limbs had been trimmed off, and a number of these lay scattered about the stump. The trunk, which must have been about eighteen feet long, had disappeared, cut into lengths of from three to six feet, probably, and started toward the harvest pile. Wondering for which house these logs were intended, I followed, hoping to trace and trail them to the house, or find them en route. From the spot where they were cut, they had evidently been rolled down a steep, grassy seventy-foot slope, at the bottom of this dragged an equal distance over a level stretch among some lodgepole pines, and then pushed or dragged along a narrow runway that had been cut through a

rank growth of willows. Once through the willows, they were pushed into the uppermost pond. They were taken across this, forced over the dam on the opposite side, and shot down a slide into the pond which contained the smaller house. Only forty-eight hours before, the little logs which I was following were in a tree, and now I expected to find them by this house. It was good work to have got them here so quickly, I thought. But no logs could be found by the house or in the pond! The folks at this place had not yet laid up anything for winter. The logs must have gone farther.

On the opposite side of this pond I found where the logs had been dragged across the broad dam and then heaved into a long, wet slide which landed them in a small, shallow harbor in the grass. From this point a canal about eighty feet long ran around the brow of the terrace and ended at the top of a long slide which reached to the big pond. This canal was new and probably had been dug especially for this harvest. For sixty feet of its length it was quite regular in form and had an average width of thirty inches and a depth of fourteen. The mud dug in making it was piled evenly along the lower side. Altogether it looked more like the work of a careful man with a shovel than of beaver without tools. Seepage and overflow from the ponds above filled and flowed slowly through it and out at the farther end, where it swept down the long slide into the big pond. Through this canal the logs had been taken one by one. At the farther end I found the butt-end log. It probably had been too heavy to heave out of the canal, but tracks in the mud indicated that there was a hard tussle before it was abandoned.

The pile of winter supplies was started. Close to the big house a few aspen leaves fluttered on twigs in the water; evidently these twigs were attached to limbs or larger pieces of aspen that were piled beneath the surface. Could it be that the aspen which I had marked on the mountain-side a quarter of a mile distant so short a time before, and which I had followed over slope and slide, through canal and basin, was now piled on the bottom of this pond? I waded out into the water, prodded about with a pole, and found several smaller logs. Dragging one of these to the surface, I found there were three notches in it.

Evidently these heavy green tree cuttings had been sunk to the bottom simply by the piling of other similar cuttings upon them. With this heavy material in the still water a slight contact with the bottom would prevent the drifting of accumulated cuttings until a heavy pile could be formed. However, in deep or swift water I have noticed that an anchorage for the first few pieces was secured by placing these upon the lower slope of the house or against the dam.

Scores of aspens were felled in the grove where the notched ones were. They were trimmed, cut into sections, and limbs, logs, and all taken over the route of the one I had followed, and at last placed in a pile beside the big house. This harvest-gathering went on for a month. All about was busy, earnest preparation for winter. The squirrels from the tree-tops kept a rattling rain of cones on the leaf-strewn forest floor, the cheery chipmunk foraged and frolicked among the withered leaves and plants, while aspens with leaves of gold fell before the ivory sickles of the beaver.

Splendid glimpses, grand views, I had of this strange harvest-home. How busy the beavers were! They were busy in the grove on the steep mountainside ; they tugged logs across the runways; they hurried them across the water-basins, wrestled with them in canals, and merrily piled them by the rude house in the water. And I watched them through the changing hours; I saw their shadowy activity in the starry, silent night; I saw them hopefully leave home for the harvest groves in the serene twilight, and I watched them working busily in the light of the noonday sun.

Most of the aspens were cut off between thirteen and fifteen inches above the ground. A few stumps were less than five inches high, while a number were four feet high. These high cuttings were probably made from reclining trunks of lodged aspens which were afterward removed. The average diameter of the aspens cut was four and one half inches at the top of the stump. Numerous seedlings

of an inch diameter were cut, and the largest tree felled for this harvest measured fourteen inches across the stump. This had been laid low only a few hours before I found it, and a bushel of white chips and cuttings encircled the lifeless stump like a wreath. In falling, the top had become entangled in an alder thicket and lodged six feet from the ground. It remained in this position for several days and was apparently abandoned; but the last time I went to see it the alders which upheld it were being cut away. Although the alders were thick upon the ground, only those which had upheld the aspen had been cut. It may be that the beaver which felled them looked and thought before they went ahead with this cutting.

Why had this and several other large aspens been left uncut in a place where all were convenient for harvest ? All other neighboring aspens were cut years ago. One explanation is that the beaver realized that the tops of the aspens were entangled and interlocked in the limbs of crowding spruces and would not fall if cut off at the bottom. This and one other aspen were the only large ones that were felled, and the tops of these had been recently released by the overturning of some spruces and the breaking of several branches on others. Other scattered large aspens were left uncut, but all of these were clasped in the arms of near-by spruces.

It was the habit of these colonists to transfer a tree to the harvest pile promptly after cutting it down. But one morning I found logs on slides and in canals, and unfinished work in the grove, as though everything had been suddenly dropped in the night when work was at its height. Coyotes had howled freely during the night, but this was not uncommon. In going over the grounds I found the explanation of this untidy work in a bear track and numerous wolf tracks, freshly moulded in the muddy places.

After the bulk of the harvest was gathered, I went one day to the opposite side of the moraine and briefly observed the methods of the Island beaver colony. The ways of the two colonies were in some things very different. In the Spruce Tree Colony the custom was to move the felled aspen promptly to the harvest pile. In the Island Colony the custom was to cut down most of the harvest before transporting any of it to the pile beside the house. Of the one hundred and sixty- two trees that had been felled for this harvest, one hundred and twenty-seven were still lying where they fell. However, the work of transporting was getting under way ; a few logs were in the pile beside the house, and numerous others were scattered along the canals, runways, and slides between the house and the harvest grove. There was more wasted labor, too, in the Island Colony. This was noticeable in the attempts that had been made to fell limb-entangled trees that could not fall. One five-inch aspen had three times been cut off at the bottom. The third cut was more than three feet from the ground, and was made by a beaver working from the top of a fallen log. Still this high-cut aspen refused to come down and there it hung like a collapsed balloon entangled in tree-tops.

Prowling hunters have compelled most beaver to work at night, but the Spruce Tree Colony was an isolated one, and occasionally its members worked and even played in the sunshine. Each day I secluded myself, kept still, and waited ; and on a few occasions watched them as they worked in the light.

One windy day, just as I was unroping myself from the shaking limb of a spruce, I saw four beaver plodding along in single file beneath. They had come out of a hole between the roots of the spruce. At an aspen growth about fifty feet distant they separated. Though they had been closely assembled, each appeared utterly oblivious of the presence of the others. One squatted on the ground by an aspen, took a bite of bark out of it, and ate leisurely. By and by he rose, clasped the aspen with fore paws, and began to bite chips from it systematically. He was deliberately cutting it down. The most aged beaver waddled near an aspen, gazed into its top for a few seconds, then moved away about ten feet and started to fell a five-inch aspen. The one rejected was entangled at the top.

Presently the third beaver selected a tree, and after some trouble in getting comfortably seated, or squatted, also began cutting. The fourth beaver disappeared and I did not see him again. While I was looking for this one the huge, aged beaver whose venerable appearance had impressed me the first evening appeared on the scene. He came out of a hole beneath some spruces about a hundred feet distant. He looked neither to right nor to left, nor up nor down, as he ambled toward the aspen growth. When about halfway there he wheeled suddenly and took an uneasy survey of the open he had traversed, as though he had heard an enemy behind. Then with apparently stolid indifference he went on leisurely, and for a time paused among the cutters, which did nothing to indicate that they realized his presence. He ate some bark from a green limb on the ground, moved on, and went into the hole beneath me. He appeared so large that I afterward measured the distance between the two aspens where he paused. He was not less than three and a half feet long and probably weighed fifty pounds. He had all his toes; there was no white spot on his body ; in fact, there was neither mark nor blemish by which I could positively identify him. Yet I feel that in my month around the colony I beheld the patriarch of the first evening in several scenes of action.

Sixty-seven minutes after the second beaver began cutting he made a brief pause ; then he suddenly thudded the ground with his tail, hurriedly took out a few more chips, and ran away, with the other two beaver a little in advance, just as his four-inch aspen settled over and fell. All paused for a time close to the hole beneath me, and then the old beaver returned to his work. The one that had felled his tree followed closely and at once began on another aspen. The other beaver, with his aspen half cut off, went into the hole and did not again come out. By and by an old and a young beaver came out of the hole. The young one at once began cutting limbs off the recently felled aspen, while the other began work on the half-cut tree ; but he ignored the work already done, and finally severed the trunk about four inches above the cut made by the other. Suddenly the old beaver whacked the ground and ran, but at thirty feet distant he paused and nervously thumped the ground with his tail, as his aspen slowly settled and fell. Then he went into the hole beneath me...

In many localities the canals or ditches dug and used by the beaver form their most necessary and extensive works. These canals require enormous labor and much skill. In point of interest they even excel the house and the dam. It is remarkable that of the thousands of stories concerning the beaver only a few have mentioned the beaver canals. These are labor-saving improvements, and not only enable the beaver to live easily and safely in places where he otherwise could not live at all, but apparently they allow him to live happily. The excavations made in taking material for house or dam commonly are turned to useful purpose. The beaver not only builds his mound-like house, but uses the basin thus formed in excavating earthy material for the house for a winter food depository. Ofttimes, too, in building the dam he does it by piling up the material dug from a ditch which runs parallel and close to the dam, and which is useful to him as a deep waterway after the dam is completed.

In transporting trees for food-supply, water transportation is so much easier and safer than land, that wherever the immediate surroundings of the pond are comparatively level the beaver endeavors to lead water out to tree groves by digging a canal from the edge of the pond to these groves. The felled trees are by this means easily floated into the pond. One of the simplest forms of beaver canal is a narrow, outward extension of the pond. This varies in length from a few yards to one hundred feet or more.

Another and fairly common form of canal is one that is built across low narrow necks of land which thrust out into large beaver ponds, or on narrow stretches of land around which crooked streams wander.

The majority of beaver ponds are comparatively shallow over the greater portion of their area. In many cases it is not easy, or even possible, to deepen them. They may be so shallow that the pond freezes to the bottom in winter except in its small deeper portion. The shallow ponds are made more usable by a number of canals in the bottom. These canals assure deep-water stretches under all conditions. Most beaver ponds have a canal that closely parallels the dam. In some instances this is extended around the pond a few yards inside the shore-line. Two canals usually extend from the house. One of these connects with the canal by the dam, the other runs to the place on the shore (commonly at the end of a trail or slide) most visited by the beaver.

In Jefferson Valley, Montana, not far from Three Forks, I enjoyed the examination of numerous beaver workings, and made measurements of the most interesting system of beaver canals that I have ever seen. The beaver house for which these canals did service was situated on the south bank of the river, about three feet above the summer level of the water and about two hundred feet north of the hilly edge of the valley. From the river a crescent-shaped canal, about thirty-five feet in length, had been dug halfway around the base of the house. Connected with this was a basin for winter food ; this was five feet deep and thirty-five feet in diameter. From this a canal extended southward two hundred and seven feet. One hundred and ten feet distant from the house was a boulder that was about ten feet in diameter. This was imbedded in about two feet of soil. Around this boulder the canal made a detour, and then resumed its comparatively straight line southward.

Over the greater portion of its length this canal was four feet wide, and at no point was it narrower than three feet. Its average depth was twenty-eight inches. For one hundred and forty-seven feet it ran through an approximately level stretch of the valley, and seepage filled it with water. A low, semi-circular dam, about fifty feet in length, crossed it at the one-hundred -and forty-seven-foot mark, and served to catch and run seepage water into it, and also to act as a wall across the canal to hold the water. The most southerly sixty feet of this canal on the edge of the foothills ran uphill, and was about four feet deep at the upper end, four feet higher than the end by the house. The dam across it was supplemented by a wall forty-eight feet further on. This wall was simply a short dam across the canal, in a part that was inclined, and plainly for the purpose of retaining water in the canal. The upper part of the canal was filled with water by a streamlet from off the slope. Apparently this canal was old, for there was growing on its banks near the house, a spruce tree, four inches in diameter, that had grown since the canal was made.

The wall or small dam which beaver build across canals that are inclined represents an interesting phase of beaver development. That these walls are built for the purpose of retaining water in the canal appears certain. They are most numerous in canals of steepest incline, though rarely less than twenty feet apart. I have not seen a wall in an almost dead-level canal, except it was there for the purpose of raising the height of the water. This wall or buttress is after all but a dam, and like most dams it is built for the purpose of raising and maintaining the level of water.

Extending at right angles westward from the end of the old canal was a newer one of two hundred and twenty-one feet. A wall separated and united the two. One hundred and sixty feet of this new canal ran along the contour of a hill, approximately at a dead level. Then came a wall, and from this the last sixty-one feet extended southward up a shallow ravine. In this part there were two walls. The upper end of the sixty-one- foot extension was nine feet higher than the house, and four hundred and twenty-eight feet distant from it. The two-hundred-and-twenty-one foot extension was from twenty-six to thirty-four inches wide, and averaged twenty-two inches deep. The entire new part was supplied with spring water, which the beaver had diverted from a ravine to the west and led by a seventy-foot ditch into the upper end of their canal. Thirty feet from the end of the canal were two burrows, evidently safe places into which the beaver could retreat in case of sudden attack

from wolves or other foe. There were two other of these burrows, one at the outer end of the old canal and the other alongside the boulder one hundred and ten feet from the house.

At the time I saw these canals, the only trees near were those of an aspen grove which surrounded the extreme end. It was autumn, and on both tributary slopes by the end of the canal, aspens were being cut, dragged, and rolled down these slopes into the upper end of the canal, then floated through its waters, dragged over and across the walls, and at last piled up for winter food in the basin by the house. In all probability this long, large canal had been built a few yards at a time, being extended as the trees near-by were cut down and used.

Where beaver long inhabit a locality it is not uncommon for them to have two or three distinct and well-used trails from points on the water's edge which lead into neighboring groves or tree-clumps. These are the beaten tracks traveled by the beaver as they go forth from the water for food, and over which they drag their trees and in saplings into the water. On steep slopes by the water these are called slides. This name is also given to places in the dam over which beaver frequently pass in their outgoings and incomings.

Commonly these trails avoid ridges and ground swells by keeping in the bottom of a ravine; logs are cut through and rolled out of the way, or a tunnel driven beneath ; obstructions are removed, or a good way made round them. Their log roads compare favorably with the log roads of woodsmen who cut with steel instead of enamel. In most old beaver colonies, where the character of the bottom of the pond permits it, there are two or more tunnels or subways beneath the floor of the principal pond. The main tunnel begins close to the foundation of the house, and penetrates the earth a foot or more beneath the water to a point on land a few feet beyond the shore-line. If there are a number of small ponds in a colony that are separated by ringers of land, it is not uncommon for these bits of land to be penetrated by a thoroughfare tunnel. These tunnels through the separating bits of land enable the beaver to go from one pond to another with out exposing themselves to dangers on land, and also offer an easy means of intercommunication between ponds when these are ice-covered. Pond subways also afford a place of refuge or a means of escape in case the house is destroyed, the dam broken, or the pond drained, or in case the pond should freeze to the bottom. Commonly these are full of water, but some are empty. On the Missouri and other rivers, where there are several feet of cut banks above the water, beaver commonly dug a steeply inclined tunnel from the river's edge to the top of a bank a few feet back. Most of this tunnel work is hidden and remains unknown. A striking example was in the Spruce Tree Colony, elsewhere described. These colonists, apparently disgusted by having their ponds completely filled with sediment which came down as the result of a cloudburst, abandoned the old colony-site. A new site was selected on a moraine, only a short distance from the old one. Here in the sod a basin was scooped out, and a dam made with the excavated material. The waters from a spring which burst forth in the moraine, about two hundred yards up the slope and perhaps one hundred feet above, trickled down and in due time formed a pond. The following year this pond was enlarged, and another one built upon a terrace about one hundred feet up the slope. From year to year there were enlargements of the old pond and the building of new pondlets, until there were seven on the terraces of this moraine. These, together with the connecting slides and canals, required more water than the spring supplied, especially in the autumn when the beaver were floating their winter supplies from pond to pond. Within the colony area, too, were many water-filled underground passages or subway tunnels. One of these penetrated the turf beneath the willows for more than two hundred feet.

While watching the autumnal activities of this colony, as described in another chapter, I broke through the surface and plunged my leg into an underground channel or subway that was half filled with water. Taking pains to trace this stream downward, I found that it emptied into the

uppermost of the ponds along with the waters from a small spring. Then, tracing the channel upwards, I found that, about one hundred and forty feet distant from the uppermost pond, it connected with the waters of the brook on which the old colony formerly had a place. This tunnel over most of its course was about two feet beneath the surface, was fourteen inches in diameter, and ran beneath the roots of spruce trees. The water which the tunnel led from the brook plainly was being used to increase the supply needed in the canals, ponds, and pools of the Spruce Tree Colony. The intake of this was in a tiny pond which the beaver had formed by a damlet across the brook. That this increased supply of water was of great advantage to the busy and populous Spruce Tree Colony, there can be no doubt. Was this tunnel planned and made for this especial purpose, or was the increased water-supply of the colony the result of accident by the brook's breaking into this subway tunnel?

The canals which beaver dig, the slides which they use, the trails which they clear and establish, conclusively show that these animals appreciate the importance of good waterways and good roads, in other words, good transportation facilities...

Lilly Lake beaver house... was a large roughly rounded affair that measured twenty-two feet in diameter. It rose only four feet above the normal water-line. This house had been three times altered and enlarged, and once raised in height. Its mud walls were heavily reinforced with polelike sticks, which were placed at the junctures of the enlargements. The one large room was more than twelve feet in diameter. Near the centre stood a support for the upper part of the house. This support was about one and a half by two and a half feet, and was composed for the most part of sticks. But few houses have this support ; commonly the room is vaulted. The room itself averaged two and a half feet high. It had four entrances.

A house commonly has two entrances, but it may have only one or as many as five. Thus the way to the outer world from the inside of the house is through one or more inclined passage-ways or tunnels. The upper opening of these entrances is in the floor a few inches above the water-level, and the lower opening in the bottom of the pond under about three feet of water. These extend at an angle through the solid foundation of the house, are about one foot in diameter and four to fifteen feet long, and are full of water almost to floor-level. This dark, windowless hut has no other entrance.

Most beaver houses stand in a pond, though a number are built on the shore and partly in the water, and still others on the bank a few feet away from the water. The external appearance and internal construction of the houses are in a general way the same, regardless of the situation or size. Most beaver houses appear conical. Measured on the water-line, they are commonly found to be slightly elliptical. The diameter on the water-line is from five to thirty-five feet, and the height above water is from three to seven feet.

A house may be built almost entirely of sticks, or of a few sticks with a larger proportion of mud and turf. In building, a small opening is left, or built around and over, which is afterwards enlarged into a room.

Houses that are built in a pond usually stand in three or four feet of water. The foundation is laid on the bottom of the pond, of the size intended for the house, and built up a solid mass to a few inches above water-level. This island-like foundation is covered with a crude hemisphere or dome-shaped house, the central portion of the foundation forming the floor of the low-vaulted room which is enclosed by the thick house-walls. In building the house the beaver provide a temporary support for the combined roof and walls by piling in the centre of the floor a two-foot mound of mud. Over this is placed a somewhat flattened tepee- or cone-shaped frame of sticks and small poles. These stand on the outer part of the foundation and lean inward with upper ends meeting against and

above the temporary support. The beaver then cover this framework with two or three feet of mud, brush, and turf, and thus make the walls and the roof of the house. When the outer part of the house is completed, they dig an inclined passageway, from the bottom of the pond up through the foundation, into the irregular space left between the supporting pile of mud and the walls. And of this space they shape a room, by clawing out the temporary support and gnawing off the intruding sticks. This represents the most highly developed type of beaver house.

In most houses the temporary support is not used, but a part of the wall is carried up to completion, and against it are leaned sticks, which rest upon the edge of the remaining foundation.

A finished house of this kind has a slightly elliptical outline. However, many a house is a crude haphazard pile of material in which a room has been burrowed. The room is from one to three feet high, and from three to twenty feet across. The room is a kind of a burrow and is without either door or window. Half-buried sticks make a comparatively dry floor, despite the fact that it is only a few inches above water-level. Beaver sleep on the floor, usually with tail bent along the side after the fashion of a dozing cat, in a nest of shredded wood, which they patiently make by thinly splitting and paring pieces of wood. Just why this kind of bedding is used cannot be said, but probably because this material dries more quickly, is more comfortable and more sanitary, and harbors fewer parasites. However, a few beds are made of grass, leaves, or moss.

But little earthy matter is used in the tip-top of the house, where the minute disjointed air-holes between the interlaced poles give the room scanty ventilation.

Except in a few cases where house-walls are overgrown with willows or grass, the erosive action of wind and water rapidly thins and weakens them. Hence the house must receive frequent repairs. Each autumn it is plastered or piled all over with sticks or mud. The mud covering varies in thickness from two to six inches. The mud for this purpose is usually dredged from the bottom of the pond close to the foundation of the house. It is carried up, a double handful at a time, the beaver waddling on his hind legs as he holds it with his fore paws against his breast. A half-dozen or more beaver may be carrying mud up at once. The covering not only thickens the walls and increases the warmth of the house, but also freezes and becomes an armor of stone that is impregnable to most beaver enemies. The "mudding" of the house is a part of the natural and necessary preparation for winter. It may also be a special means of protection deliberately carried out by the beaver. The fact that an occasional thick-walled or grass-covered beaver house was not thus plastered in autumn perhaps because it did not need it has led a few people to affirm that beaver houses are not mud-covered in the autumn. Many years of observation show that most beaver houses do receive an autumnal plastering, and the few that do not have this attention usually have thick, well-preserved walls and do not need it.

One autumn in Montana, of twenty-seven beaver houses which I examined, twenty-one received mud covering; three of the others were thickly overgrown with willows and two were grass-grown. Only one thin-walled house that needed reinforcement did not receive it; and this one, by the way, was broken into by a bear before the winter had got fairly under way.

Beaver frequently show good judgment in that important matter of selecting a site for the house. Ice and sediment are two factors with which the beaver must constantly contend. In the pond the house is commonly placed in deep water, and apparently where the depth around it will not be rapidly reduced by the depositing of sediment. Keeping the house-entrance, the harvest-pile basin, and the canals from filling with sediment is one of the difficult problems of beaver life.

To guard against the rapid encroachments of the deposits of sediment, one group of beaver, apparently with forethought, built a dam that formed a pond from the waters of a small spring which carried but little or no sediment. I have noticed a number of instances in which a pond was

made on a small streamlet with greater labor than it would have required to form a pond in a near-by brook. As there were a number of other conditions favorable to the brook situation of the house, the only conclusion I could reach was that these selections for colony-sites were made with the intention of avoiding the ever-encroaching sediment, for in some beaver ponds this sediment is deposited annually to the depth of several inches.

Ice is one of the troubles of beaver existence. It is of the utmost importance to the beaver that he should have his house so situated that the ice of winter does not close the entrance to it, and also that the deep water in which his pile of green provisions is deposited does not freeze solid and thus exclude him from the food- supply. The ice fills the pond from the top and compels him to be constantly vigilant to save himself from its encroachments. Many a beaver home has been built alongside a spring, around which the beaver dredged a deep hole and in this deposited the winter food-supply. The constant flow of the spring water prevented thick ice from forming, both around the food-pile and between it and the house-entrance.

Large numbers of beaver do not possess a house. Beaver who live without a dam or pond commonly do not build a house, but are content with a burrow or a number of burrows in the banks of the waters which they inhabit. In the severe struggle to live, there is a tendency on the part of the beaver to avoid the building of dams and houses, as these reveal their presence and put the aggressive trapper on their trail. Many colonies have both houses and burrows...

while studying glaciation on the slope of Long's Peak, I came upon a cluster of eight beaver houses... It was the busiest time of the year for these industrious folk. General and extensive preparations were now being made for the long winter amid the mountain snows. A harvest of scores of trees was being gathered and work on a new house was in progress, while the old houses were receiving repairs. It was a serene autumn day when I came into the picturesque village of these primitive people. The aspens were golden, the willows rusty, the grass tanned, and the pines were purring in the easy air... A number of beavers were busy gnawing down aspens, while others cut the felled ones into sections, pushed and rolled the sections into the water, and then floated them to the harvest piles, one of which was being made beside each house.

Some were quietly at work spreading a coat of mud on the outside of each house. This would freeze and defy the tooth and claw of the hungriest or the strongest predaceous enemy. Four beavers were leisurely lengthening and repairing a dam. A few worked singly, but most of them were in groups. All worked quietly and with apparent deliberation, but all were in motion, so that it was a busy scene...What a stirring exhibition of beaver industry and forethought I viewed from my boulder-pile!

At times upward of forty of them were in sight. Though there was a general cooperation, yet each one appeared to do his part without orders or direction. Time and again a group of workers completed a task, and without pause silently moved off, and began another. Everything appeared to go on mechanically. It produced a strange feeling to see so many workers doing so many kinds of work effectively and automatically. Again and again I listened for the superintendent's voice ; constantly I watched to see the overseer move among them; but I listened and watched in vain. Yet I feel that some of the patriarchal fellows must have carried a general plan of the work, and that during its progress orders and directions that I could not comprehend were given from time to time.

The work was at its height a little before mid-day. Nowadays it is rare for a beaver to work in daylight. Men and guns have prevented daylight workers from leaving descendants. These not only worked but played by day. One morning for more than an hour there was a general frolic, in which the entire population appeared to take part. They raced, dived, crowded in general mix-ups, whacked the water with their tails, wrestled, and dived again. There were two or three play-centres,

but the play went on without intermission, and as their position constantly changed, the merrymakers splashed water all over the main pond before they calmed down and in silence returned to work. I gave most attention to the harvesters, who felled the aspens and moved them, bodily or in sections, by land and water to the harvest piles. One tree on the shore of the pond, which was felled into the water, was eight inches in diameter and fifteen feet high. Without having even a limb cut off, it was floated to the nearest harvest pile. Another, about the same size, which was procured some fifty feet from the water, was cut into four sections and its branches removed; then a single beaver would take a branch in his teeth, drag it to the water, and swim with it to a harvest pile. But four beavers united to transport the largest section to the water. They pushed with fore paws, with breasts, and with hips. Plainly it was too heavy for them. They paused. "Now they will go for help," I said to myself, "and I shall find out who the boss is." But to my astonishment one of them began to gnaw the piece in two, and two more began to clear a narrow way to the water, while the fourth set himself to cutting down another aspen. Good roads and open waterways are the rule, and perhaps the necessary rule, of beaver colonies...

It was autumn when these beaver pioneers came to Lily Lake's primitive and poetic border. The large green leaves of the pond-lily rested upon the water, while from the long green stems had fallen the sculptured petals of gold ; the willows were wearing leaves of brown and bronze, and the yellow tremulous robes of the aspens glowed in the golden sunlight. These fur-clad pioneers made a dugout a hole in the bank and busily gathered winter food until stopped by frost and snow; then, almost care-free, they dozed away the windy winter days while the lake was held in waveless ice beneath the drifting snow.

The next summer a house was built in the lily pads near the shore. Here a number of children were born during the few tranquil years that followed. These times came to an end one bright midsummer day. Lord Dunraven had a ditch cut in the outlet rim of the lake with the intention of draining it that his fish ponds, several miles below in his Estes Park game-preserve, might have water. A drouth had prevailed for several months, and a new water-supply must be had or the fish ponds would go dry. The water poured forth through the ditch, and the days of the colony appeared to be numbered.

A beaver must have water for safety and for the ease of movement of himself and his supplies. He is skillful in maintaining a dam and in regulating the water-supply; these two things require much of his time. In Lily Lake the dam and the water question had been so nicely controlled by nature that with these the colonists had had nothing to do. However, they still knew how to build dams, and water-control had not become a lost art. The morning after the completion of the drainage ditch, a man was sent up to the lake to find out why the water was not coming down. A short time after the ditch-diggers had departed, the lowering water had aroused the beaver, who had promptly placed a dam in the mouth of the ditch. The man removed this dam and went down to report. The beaver speedily replaced it. Thrice did the man return and destroy their dam, but thrice did the beaver promptly restore it.

The dam-material used in obstructing the ditch consisted chiefly of the peeled sticks from which the beaver had eaten the bark in winter ; along with these were mud and grass. The fourth time that the ditch guard returned, he threw away all the material in the dam and then set some steel traps in the water by the mouth of the ditch. The first two beaver who came to reblockade the ditch were caught in these traps and drowned while struggling to free themselves. Other beaver heroically continued the work that these had begun. The cutting down of saplings and the procuring of new material made their work slow, very slow, in the face of the swiftly escaping water; when the

ditch was at last obstructed, a part of the material which formed this new dam consisted of the traps and the dead bodies of the two beaver who had bravely perished while trying to save the colony.

The ditch guard returned with a rifle, and came to stay. The first beaver to come within range was shot. The guard again removed the dam, made a fire about twenty feet from the ditch, and planned to spend the night on guard, rifle in hand. Toward morning he became drowsy, sat down by the fire, heard the air in the pines at his back, watched the star-sown water, and finally fell asleep. While he thus slept, with his rifle across his lap, the beaver placed another their last obstruction before the outrushing water. On awakening, the sleeper tore out the dam and stood guard over the ditch. All that after- noon a number of beaver hovered about, watching for an opportunity to stop the water again.

Their opportunity never came, and three who ventured too near the rifleman gave up their lives, reddening the clear water with their life-blood in vain. The lake was drained, and the colonists abandoned their homes. One night, a few days after the final attempt to blockade the ditch, an unwilling beaver emigrant party climbed silently out of the uncovered entrance of their house and made their way quietly, slowly, beneath the stars, across the mountain, descending thence to Wind River, where they founded a new colony.

Winter came to the old lake-bed, and the lily roots froze and died. The beaver houses rapidly crumbled, and for a few years the picturesque ruins of the beaver settlement, like many a settlement abandoned by man, stood pathetically in the midst of wilderness desolation. Slowly the water rose to its old level in the lake, as the outlet ditch gradually filled with swelling turf and drifting sticks and trash. Then the lilies came back with rafts of green and boats of gold to enliven this lakelet of repose...

One autumn morning, while returning to my cabin after a night near the stars on Lily Mountain, I paused on a crag to watch the changing morning light down Wind River Canon. While thus engaged, Flat-top [the name of one of the individual beavers Enos Mills was observing –A.B. & M.C.] and a party of colonists came along a game trail within a few yards of me, evidently bound for the lake, which was only a short distance away. I silently followed them. This was my introduction to Flat-top. On the shore these seven adventurers paused for a moment to behold the scene, or, possibly, to dream of empire ; then they waddled out into the water and made a circuit of the lake. Probably

Flat-top had been here before as an explorer. Within two hours after their arrival these colonists began building for a permanent settlement. It was late to begin winter preparation. The clean, white aspens had shed their golden leaves and stood waiting to welcome the snows. This lateness may account for the makeshift of a hut which the colonists constructed. This was built against the bank with only one edge in the water ; the entrance to it was a twelve-foot tunnel that ended in the lake-bottom where the water was two feet deep.

The beaver were collecting green aspen and willow cuttings in the water by the tunnel-entrance when the lake froze over. Fortunately for the colonists, with their scanty supply of food, the winter was a short one, and by the first of April they were able to dig the roots of water plants along the shallow shore where the ice had melted. One settler succumbed during the winter, but by summer the others had commenced work on a permanent house, which was completed before harvest time.

I had a few glimpses of the harvest-gathering and occasionally saw Flat-top. One evening, while watching the harvesters, I saw three new workers. Three emigrants from somewhere had joined the colonists. A total of fifteen, five of whom were youngsters, went into winter quarters, a large, comfortable house, a goodly supply of food, and a location off the track of trappers. The cold,

white days promised only peace. But an unpreventable catastrophe came before the winter was half over.

One night a high wind began to bombard the ice-bound lake with heavy blasts. The force of these intermittent gales suggested that the wind was trying to dislodge the entire ice covering of the lake; and indeed that very nearly happened. Before the crisis came, I went to the lake, believing it to be the best place to witness the full effects of this most enthusiastic wind. Across the ice the gale boomed, roaring in the restraining forest beyond. These broken rushes set the ice vibrating and the water rolling and swelling beneath. During one of these blasts the swelling water burst the ice explosively upward in a fractured ridge entirely across the lake. In the next few minutes the entire surface broke up, and the wind began to drive the cakes upon the windward shore.

A large flatboat cake was swept against the beaver house, sheared it off on the water-line, and overturned the conelike top into the lake. The beaver took refuge in the tunnel which ran beneath the lake-bottom. This proved a death- trap, for its shore end above the water-line was clogged with ice. As the lake had swelled and surged beneath the beating of the wind, the water had gushed out and streamed back into the tunnel again and again, until ice formed in and closed the outer entrance. Against this ice four beaver were smothered or drowned. I surmised the tragedy but was helpless to prevent it. Meanwhile the others doubled back and took refuge upon the ruined stump of their home. From a clump of near-by pines I watched this wild drama.

Less than half an hour after the house was wrecked, these indomitable animals began to rebuild it. Lashed by icy waves, beaten by the wind, half-coated with ice, these home-loving people strove to rebuild their home. Mud was brought from the bottom of the pond and piled upon the shattered foundation. This mud set froze almost instantly on being placed. They worked desperately, and from time to time I caught sight of Flat-top. Toward evening it appeared possible that the house might be restored, but, just as darkness was falling, a roaring gust struck the lake and a great swell threw the new part into the water.

The colonists gave up the hopeless task and that night fled down the mountain. Two were killed before they had gone a quarter of a mile. Along the trail were three other red smears upon the crusted snow; each told of a death and a feast upon the wintry mountain-side among the solemn pines. Flat-top with five others finally gained the Wind River Colony, from which he had led his emigrants two years before.

One day the following June, while examining the lilies in the lake, I came upon a low, freshly cut stump; Flat-top had returned. A number of colonists were with him and all had come to stay. All sizable aspen that were within a few yards of the water had been cut away, but at the south-west corner of the lake, about sixty feet from the shore, was an aspen thicket. Flat-top and his fellow workers cut a canal from the lake through a low, sedgy flat into this aspen thicket. The canal was straight, about fourteen inches deep and twenty-six inches wide. Its walls were smoothly cut and most of the excavated material was piled evenly on one side of the canal and about eight inches from it. It had an angular, mechanical appearance, and suggested the work not of a beaver, but of man, and that of a very careful man too.

Down this canal the colonists floated the timbers used in building their two houses. On the completion of the houses, the home-builders returned to the grove and procured winter supplies. In most cases the small aspen were floated to the pile between the houses with an adept skill, without severing the trunk or cutting off a single limb...Year after year the regularly equipped trappers passed the lake without stopping. The houses did not show distinctly from the trail, and the trappers did not know that there were beaver in this place. But this peaceful, populous lake was not forever to

remain immune from the wiles of man, and one day it was planted with that barbaric, cruel torture-machine, the steel trap...

The ruinous raid of the trappers was followed by a dry season, and during the drouth a rancher down the mountain came up prospecting for water. He cut a ditch in the outlet ridge of the lake, and out gushed the water. He started home in a cheerful mood, but long before he arrived, the "first engineers" had blocked his ditch. During the next few days and nights the rancher made many trips from his house to the lake, and when he was not in the ditch, swearing, and opening it, the beaver were in it shutting off the water.

From time to time I dropped around to see the struggle, one day coming upon the scene while the beaver were completing a blockade. For a time the beaver hesitated ; then they partly resumed operations and carried material to the spot, but without showing themselves entirely above water. When it appeared that they must have enough to complete the blockade, I advanced a trifle nearer so as to have a good view while they placed the accumulated material. For a time not a beaver showed himself. By and by an aged one climbed out of the water, pretending not to notice me, and deliberately piled things right and left until he had completed the ditch-damming to his satisfaction. This act was audacious and truly heroic. The hero was Flat-top.

In this contest with the rancher, the beaver persisted and worked so effectively that they at last won and saved their homes, in the face of what appeared to be an unconquerable opposition. A little while after this incident, a home-seeker came along, and, liking the place, built a cabin in a clump of pines close to the southern shore. Though he was a gray old man without a family, I imagined he would exterminate the beaver and looked upon him with a lack of neighborly feeling.

Several months went by, and I had failed to call upon him, but one day while passing I heard him order a trapper off the place. This order was accompanied by so strong a declaration of principles together with a humane plea for the life of every wild animal that I made haste to call that evening.

One afternoon in a pine thicket, close to the lake-shore, I came upon two gray wolves, both devouring beaver, which had met their death while harvesting aspens for winter. The following spring I had a more delightful glimpse of life in the wilds. Within fifty feet of the lakeshore stood a large pine stump that rose about ten feet from the ground. Feeling that I should escape notice if I sat still on the top, I climbed up. Though it was mid-forenoon, the beaver came out of the lake and wandered about nibbling here and there at the few green plants of early spring. They did not detect me. They actually appeared to enjoy themselves. This is the only time that I ever saw a beaver fully at ease and apparently happy on land. In the midst of their pleasures, a flock of mountain sheep came along and mingled with them. The beaver paused and stared; now and then a sheep would momentarily stare at a beaver, or sniff the air as though he did not quite like beaver odor. In less than a minute the flock moved on, but just as they started, a beaver passed in front of the lead ram, who made a playful pretense of a butt at him; to this the beaver paid not the slightest heed.

During the homesteader's second summer he concluded to raise the outlet ridge, deepen the water, and make a fish pond of the lake. Being poor, he worked alone with wheelbarrow and shovel. The beaver evidently watched the progress of the work, and each morning their fresh footprints showed in the newly piled earth. Shortly before the dam was completed, the homesteader was called away for a few days, and on his return he was astonished to find that the beaver had completed his dam! The part made by the beaver suited him as to height and length, so he covered it over with earth and allowed it to remain. His work in turn was inspected and apparently approved by the beaver....

While visiting ponds at the beginning of winter, I have many times noticed that, shortly after the pond was solidly frozen over, a hole was made through the dam just below the water-surface of the pond. This lowered the water-level two inches or more. Did this slight lowering of the water have to do with the ventilation of the ice-covered pond, or was it to put a check on deep freezing, or for both purposes ? ...

The beaver's conservation work is accomplished by means of the dams he constructs across streams of flowing water and the ponds that are thus formed. These dams and ponds render a number of services: first, they save soil; second, they check erosion ; third, they reduce flood damage; fourth, they store water and help to sustain stream-flow; fifth, they provide water-holes for fish ; and sixth, they are helpful in maintaining deep waterways by reducing the extremes of both high and low water, and also by reducing the quantity of sediment carried down into river-channels.

I had enjoyed the ways of "our first engineers " before it dawned upon me that their works might be useful to man, and that the beaver through his constructive handling of the natural resources might justly be called a conservationist. One dry winter the stream through the Moraine Colony ran low and froze to the bottom, and the only trout in it that survived were those in the deep holes of beaver ponds. These ponds offer many advantages to fish multiplication. Much food acceptable to the fish is swept into these ponds. Altogether a beaver pond is an excellent local habitation for fish.

One gray day while I was examining a beaver colony there came another demonstration of the usefulness of beaver ponds. The easy rain of two days ended in a heavy downpour a deluge upon the mountain-side a mile or so upstream. There was almost nothing on this mountain either to absorb or delay the excess of water which was speedily shed into the stream below. Flooding down the stream's channel above the beaver pond, came a roaring avalanche of water, or water-slide, with a rubbish-filled front that was five or six feet high. This expanded as it rolled into the pond, and swept far out on the sides, while the water-front, greatly lowered, rushed over the dam. A half a dozen ponds immediately below sufficed so to check the speed of this water and so greatly to reduce its volume that as it poured over the last dam of this colony it was no longer a flood.

The regulation of stream-flow is important. There are only a few rainy days each year, and all the water that flows to the sea through river- channels falls during these few rainy days. The instant the water reaches the earth it is hurried away by gravity, and unless there are factors to delay this run-off, the rivers would naturally contain water only on the rainy days and for a little while thereafter. A beaver dam and pond together form a factor of importance in the keeping of streams ever flowing. The pond is a reservoir which catches and retains some of the water coming into it during rainy days and which delays the water-flow through it. A beaver pond is a leaky reservoir, a kind of spring as it were, and if stored full during rainy days the leakage from it will help maintain stream-flow below during the dry weather. Beaver works thus tend to distribute to streams a moderate quantity of water each day. In other words they spread out or distribute the water of the few rainy days through all the days of the year.

A river which flows steadily throughout the year is of inestimable value to mankind. If floods sweep a river, they do damage. If low water comes, the wheels of steamers and of factories cease to move, and a dry river-channel means both damage and death. Numerous beaver colonies along the sources of countless streams that rise in the hills and the mountains would be helpful in equalizing the flow of these streams. I hope and believe that before many years every rushing care-free brook that springs from a great watershed will be steadied in a poetic pond that is made, and that will be maintained by our patient, persevering friend the beaver. In the West beaver are peculiarly useful at stream-sources, where their ponds store flood waters that may later be used for stock water or for

irrigation purposes. There are a number of localities in New Mexico, South Dakota, and elsewhere in the West where beaver receive the utmost protection and encouragement from ranchers, whose herds are benefited by water conveniently stored in beaver ponds. A few power companies in the country have commenced to stock with beaver the watersheds which supply them with water. They do this because they realize that countless small ponds or reservoirs are certain to be constructed by these little conservationists.

Running water dissolves and erodes away the earthy materials with which it comes in contact. The presence of a beaver pond and dam across a stream's highway prevents the wearing and the carrying away of material. They not only prevent erosion or wearing away, but they take soil and sediment from the water which comes to them and thus cause an upbuilding. Hence the presence of beaver ponds along streams causes an accumulation of sediment and soil. In time these fill rocky channels and canons, widen and lengthen valleys, and thus extend the productive area of the earth.

Beaver ponds are settling-basins, and in them are deposited the heavier matter brought in by the stream. In time the pond is filled, and if the beaver do not raise the height of the dam, the accumulated earthy matter becomes covered with flowers or forests...

A few centuries ago there were millions of beaver ponds in North America ; most of these were long since filled with sediment. Since then, too, countless others have been formed and filled. This soil-saving and soil-spreading still goes ever on wherever there is a beaver pond. Many of the richest tillable lands of New England were formed by the artificial works of the beaver. There are hundreds of valleys in Kansas, Kentucky, Missouri, Illinois, and other States whose rich surface was spread upon them by the activities of beaver through generations. In the Southern States and in the mountains of the West, the numbers of beaver meadows are beyond computation. The aggregate area of rich soil- deposits in the United States for which we are indebted to the beaver is beyond belief, and probably amounts to millions of acres.

The beaver have thus prepared the way for forests and meadows, orchards and grain-fields, homes and school-houses. In the golden age of the beaver, their countless colonies clustered all over our land. These primeval folk then gathered their harvest. Innumerable beaver ponds, which then shone everywhere in the sun, slowly filled with deposited, outspreading soil, and vanished. Elm avenues now arch where the low-growing willow drooped across the canal, and a populous village stands upon the seat of a primitive and forgotten colony.

A live beaver is more valuable to mankind than a dead one. As trappers in all sections of the country occasionally catch a beaver, it is probable that there still are straggling ones scattered along streams all the way from salt water up to timber-line, twelve thousand feet above sea- level. These remaining beaver may be exterminated ; but if protected they would multiply and colonize stream-sources. Here they would practise conservation. Their presence would reduce river and harbor appropriations and make rivers more manageable, useful, and attractive. It would pay us to keep beaver colonies in the heights. Beaver would help keep America beautiful. A beaver colony in the wilds gives a touch of romance and a rare charm to the outdoors. The works of the beaver have ever intensely interested the human mind. Beaver works may do for children what schools, sermons, companions, and even home sometimes fail to do, develop the power to think. No boy or girl can become intimately acquainted with the ways and works of these primitive folk without having the eyes of observation opened, and acquiring a permanent interest in the wide world in which we live. A race which can produce mothers and fathers as noble as those beaver in the Grand Canyon who offered their lives hoping thereby to save their children is needed on this earth. The beaver is the Abou-ben-Adhem of the wild. May his tribe increase!

The New Deep Hoeing Husbandry

Though the agricultural practices of our times have come to differ from the principles of ancient times, the student of agriculture should not be discouraged from learning from their ancestors, for in the works of the ancients there is more to be found to merit our approval than our rejection.

When a venture turns out unsuccessfully through wrong management, you may avoid the mistake that you made before. As the instructions of a teacher cast light upon the right course, these teachings we offer not to bring the science to perfection, but to lend a helping hand. No one will immediately become a master of agriculture by the reading of books unless they have the will and resources to put them into practice. We set them forth, therefore, to help those who wish to learn – not to be beneficial all alone, but in conjunction with the lessons of experience.

It is right that those who have an earnest desire to investigate subjects of the greatest utility for the human race and to transmit to posterity the carefully weighed findings should try everything. And if the force of an outstanding genius or the equipment of celebrated arts is wanting, we should not immediately relapse into idleness and sloth, but rather that which we have wisely hoped for we should steadfastly pursue. Even if we fail our aim for the topmost peak, it will be honor enough for us to even be seen on the second summit!

—Lucius Junius Moderatus Columella, *On Agriculture*

CHAPTER TWENTY-TWO: OF RESOURCE AND LABOR MANAGEMENT: FARM ECONOMICS

Human and animal labor are kinds of resources, all resources require management

Both human and animal labor are kinds of resources, and as such require management like any other resource would. In this chapter, the tools and practices of resource management will be discussed with a focus on animal and human labor management.

All resources can be expressed in terms of potential industrial application, money, energy and time.
Definitions of industry, money, energy and time

All resources can be expressed in terms of potential industrial application, money, energy and time.

Industry is a term used to describe the application of resources to "induce" the production of goods. Goods is the term used to describe quantitative units of resources, generally expressed in terms of time, energy and money.

Money is a term used to describe the equivocal worth of valuable goods when exchanged for other goods: it is the worth of any two different goods in terms of a third good (For example, 1 pound of beans is worth 2 pounds of corn, and when expressed in terms of money, both 1 pound of beans and 2 pounds of corn are worth each 1 Dollar; a more complex example is a human laborer is worth a bowl of food per hour, and that both a bowl of food and an hour of human labor is worth 1 Dollar).) Metal is typically used as that neutral third good by which other goods are estimated, and among the metals, gold, silver, copper, lead, zinc, nickel and various alloys are used interchangeably. The reason why metals are typically used is because they are easily divided into minute parts, and their weight when pure is easily knowable. It is their consistency and divisibility that makes them uniquely suited to be the material of money.

Energy is usually expressed in terms of Calories, British Thermal Units, Watts, or Horsepower, and is based upon the time such energy would boil either salt or sweet water, or the time that an object of known weight can be pulled a certain distance on a surface of no frictional resistance. These are good estimators of energy. It should be noted that time is an essential component of energetic measurement: measurements of energy are undertaken to study the changes in valuable goods over time; energy is a measurement of change, either the amount of change that has been effected or the amount of change that has occurred. Because of this, energy is a saleable commodity: farmers will exchange money to effect changes.

Time is usually expressed in seconds, minutes, hours, arcs or in other divisions of an arc. As mentioned in a footnote in the Chapter on Wheat, the first units of physical distance were measured by observing the rate at which the Earth rotated on its axis by observing the course of stars in the

sky. Time, then, was discovered by observing the rate of repetition and defined by the frequency that a star would return to its original position along an arc.

Animals tend to diversify their development, exploration and exploitation of resources because it helps them survive emergencies and climate shifts

Mark Twain writes in Puddin' Head Wilson, "The fool saith, 'Put not all thy eggs in one basket' – which is but a manner of saying, "scatter your money and attention; but the wise man saith, "Put all your eggs in one basket, and – WATCH THAT BASKET!" While this is a viable philosophy for resource management, the tendency of animals and humans, built upon the sound science of risk analysis, is to not put all the eggs in one basket.

All creatures tend to diversify their development, exploration and exploitation of resources. There are exceptions: some animals rely on a single kind of plant resource for their survival, and some plants rely on a single kind of animal resource for their survival, some microorganisms eat only one kind of mineral, etc. But by and large, just as a diversified stock portfolio averages to the market's tide and is less susceptible to the risks of a single company's poor decisions, animals with a wealth of diversified resources survive emergencies and extraordinary situations better than those who do not.

And survival is the game that every species plays.

Animals rarely rely wholly on one source of water, nor one source of food. They are always exploring new resources, too: in the event that a primary shelter is destroyed or rendered unusable for any number of reasons, several alternative shelters have been explored and are ready for use.

Enos Mills, the American Naturalist, observed that many animals "vacation" when they have the opportunity to discover new terrain, and the resources there. He records evidence of picas, bears, beavers, lions, and many other creatures setting out with no other intention except to discover neighboring territories. These were not hunting or food gathering trips, nor any aggressive action upon their neighbors, but simply explorations and amount to self-education and self-training, an essential component of adult animal development: after the animal can no longer rely on its parents to develop it, it must develop itself. Animals will try new foods whenever possible: in a time when their favorite food is not available, they will have another resource.

Diversification is a wise strategy, made wiser when new resources are developed for emergencies.

A farmer who tries new things, explores the resources of their farm and themselves, of understands how to improve those resources through diversification (the process opposite to specialization) is very wise. Just as a farmer should not rely on only one crop, they should diversify their other resources. Thus, the labor they train and the equipment they obtain, every one of their buildings, must be able to perform multiple functions and undertake diverse kinds of production in the event of an emergency or a market shift (which, to an undiversified and unprepared farmer, amounts to the same thing) – just as the majority of their fellow creatures prepare for shifts of climate or other emergencies.

Labor management requires developing the labor's ability to use existing resources and providing resources to the labor to use; labor is valued by its resource efficiency

Labor management requires developing the labor's ability to use existing resources and providing resources to the labor to use.

If managed improperly, labor will be inefficient with resources and decrease profit for a farm or any company. Yet labor can be managed well and improve resource efficiency. The quality of labor should be measured in terms of resource efficiency.

Managers are special classes of laborers that have as their responsibility the efficiency of other laborers; managers have authority over other classes of labor to allow them to organize and direct the application of resources; managers must calculate the cost of wasted resources against the cost of reducing (conserving) wasted resources (improving efficiency): if a resource costs more to conserve than to waste, the manager must identify ways to increase efficiency more affordably

Manager is the term used to describe those laborers which have as their responsibility the efficiency of other laborers. Thus, this specialized class of labor is characterized by having decision making power and authority over other classes of labor to allow them to organize and direct the application of resources.

To do so, the manager must calculate the cost of the wasted resources against the cost of reducing (conserving) the wasted resources, and identify and implement solutions that maximize profit for the firm. If a resource costs more to conserve than to waste, the resource is justifiably wasted unless the manager can identify a way to increase efficiency more affordably.

The wise manager will understand that there will always be inefficiency, but that the inefficiency can be reduced to the point when it would cost more than it would return to fix it further...and then learn and develop new ways to fix the inefficiency at less cost!

Process of management is easy: observe efficiency of resources by labor, analyze to identify amount of and causes of inefficiency, then take corrective actions if the cost of doing so is justified.

This process is straightforward: the manager observes the efficiency of the labor, analyzes it to identify the amount of and causes of the inefficiency, and then take corrective actions if the cost of doing so is justified.

Managers must identify those failures of efficiency which are statistically significant, and accept that some failure must occur: it is not cost effective to have 0% inefficiency. The several kinds of failures which lead to statistically resource inefficiency

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In completing a task, there are several failures which lead to statistically significant resource inefficiency.

1. Basic management failure. The efficiency of industry is unable to improve further cost effectively and demonstrates a failure of management to identify ways of improving production.
2. Complex management (environmental) failure. The workspace, tools, materials, training and other requirements of the labor's industry are not being met by management. Changes to the workspace, tools, materials, training and other requirements of the labor's industry will increase efficiency. Some examples of this failure would be forcing labor to use broken tools, not providing enough ladders or boxes to orchard harvesters, etc.
3. Systematic failure. Standards of production by which efficiency is measured are not practical or realistic, and must be changed: in example, when punching circular holes in a square sheets, there must be wasted resources and unless the manager is savvy enough to change the system by recycling the wasted corners or finding some other use for them, labor will never become more efficient in production. Another example is found when three squash seeds must be planted in one place because there is only a 33% germination rate: unless the manager can find better squash seed, labor must be inefficient in planting. The difference between a systematic failure and a basic management failure is that in a systematic failure, the standard of efficiency is causing statistically significant errors and changing the standard removes the error.
4. Terminal failure. This failure originates before or after industry is undertaken by the laborer and includes situations when a manager or laborer refuses to follow directions, or is incapacitated through mental or physical disease. An example is found in a laborer who is to ascertain seed viability through dissection of seed: they ought to have good eyesight for if they do not, and do not get corrective lenses to overcome their disease, they will not record a correct viability rate, and too much or too little seed will be planted. Another example is in the use of an old horse that should have been retired long ago: the old horse simply cannot work as well as they need to because of the illnesses of age. A third example is in a young horse or inexperienced human laborer who has not yet learned their job: the directions and training of their manager is insufficient. A fourth example is in a manager who cannot provide instructions in a comprehensible way to the laborers. A manager who is a tyrant falls into this category, as they have been improperly trained and must be retrained. What makes terminal failure different from complex management (environmental) failure is that in terminal failure, the manager or laborer is making error, and it is not the environment causing the laborer or manager to make the error.
5. Intentional error. The laborer or manager intentionally does not do their job through laziness, through malice or in some other act of sabotage. This is only cured through the employee leaving the company.

Managers should not only praise laborers, but encourage laborers to praise each other

The manager cannot always praise the laborer who is doing a good job adequately. It is important to recognize those employees that increase the efficiency of resources, but more important still to encourage employees to praise each other. This is done by rewarding and paying everyone on the manager's team or gang equally and promoting to management (and greater pay) those expert laborers who increase efficiency AND those managers who have promoted those expert laborers: both have done good service to the company, and the expert can train their former fellows to do as well as they did, raising the total efficiency of the workplace. With bonuses and pay equally shared,

the employees then find it in their interests to praise and promote those heroes among themselves that do the best work, and to emulate their strong example.

Never should one member of a team or gang be rewarded when none of the other members of the team or gang are rewarded: this will decrease morale, and not provide incentives towards improvement. Production is a team effort, and every member of the gang should be recognized for their contribution to the industry.

Manager as inspiration and teacher matures laborers into managers, eventually allowing all employees to simultaneously serve and be served

It is natural that an employee who is highly skilled should be given management duties so that they may help others achieve the greatness they have obtained. We encourage the strongest among us to do those heroic tasks that only the strongest can do so that those who are weaker do not lapse into the slothfulness and idleness of despair: if we fail by aiming at the topmost peak and arrive only at the second summit, we enjoy enough honor when we can offer a hand up to those who are struggling behind us; a person risks dishonor only by not trying to be as strong as they can. We are *required* to try to be as strong as we can so that we can help those who are weaker. No one is born so strong that they cannot become stronger. The might and goodness of a parent does not dismay their child: the child is inspired to do better than their parents. So should a manager inspire greatness within their team or gang.

When at last a manager has become a teacher of teachers, empower them with ownership of resources and the resulting directorship; allow them to direct the course of their self improvement. Their interests will lie in the interests of the company, and serving them brings reward to the entire farm. It is in your interests to ensure that every employee achieves the full potential of their adulthood, and a farm has never suffered for too many skilled laborers.

Labor should be inspired to do better than their management could ever hope them to do. Every task given to them by their management should be a chance to prove their worth; labor should actively seek ways to prove their worth to the company knowing that their labors will be greatly rewarded. The company and management should be known to reward...and to fairly give everyone a chance to do their best and achieve those rewards.

When an employee has risen through the ranks of management, how does the company retain the employee's dedication and prevent them from lapsing into idleness? Greater and greater challenges must be provided to the employees so that they are always made to be equal to the challenge. What greater challenge is there than ownership? Whenever a laborer has proven themselves worthy of the challenge, they should be given the immense responsibility of establishing a new company, a new market, a new product. They should be given the task of expanding the operations of the company.

When a manager has learned enough to operate their own company, if they are not given the opportunity to expand their company, they will seek to form their own company in rebellion or competition to their parent company (sometimes, to compound the disaster, stealing valuable human resources from their parent company). It is far better for the parent company to embrace these fully mature managers with the gift of their own allied venture than to face these grown laborers in competition.

Franchising or subsidization is an excellent option for a farm whose management has matured: this can occur in any number of ways but was best demonstrated by the scientist JY

Cousteau who would give to his leading men the command of a vessel in his fleet, or the command and design of an important project. Thus, an employee would be manager one day, and laborer the next, serving and served alternatively as the needs of the company required.

Of course, most farmers do not have ships, but always should be designing some new project, whether that is a new crop, a value-added production or some other diversification.[338] The worthy

[338] Samsel Millwork and Sawshop of Hancock, Wisconsin, has pioneered a better lumber since 1952 when father and son LG and Clyde Samsel undertook to plant 80 acres of open field and oak savannah with lumber trees. Since then, some 200,000 trees have been planted and the forest has been thinned three times, the lumber processed at the Samsel sawmill. Tree farms have such a long turn-around that they require the farmer subsidize the investment for 20-40 years through other labor or cultivation and thus require an intimate labor/management relationship.

While many tree farmers will gradually shift production from conventional crops to lumber to ease this transition, or invest in auxiliary acreages for lumber farming, the Samsel farm was begun at a go with 120 acres planted at once, not coming into its own sustainable profitability for two generations of farmers.

The property was originally purchased as a hobby farm by LG, who had an agricultural degree and worked as an advertising copywriter for the JI Chase Company. Clyde, only 16 at the time, invested his college savings and bought an adjacent 40 acre section. Though he had to work his way through college (obtaining a Master's degree in Chemical Engineering from the University of Wisconsin) and completing military service in the US Army, Clyde married his junior high school sweetheart, Janet Flynn after she earned her nursing degree.

During the next 27 years, Clyde worked for the SC Johnson & Co. (where he was responsible for hiring the first female chemical engineer in the industry and not discriminating against handicapped individuals) while raising his children Barbara and Jay with Janet. Janet, for her part, became President of the Lakeshore Chapter of the Red Cross, teaching new baby classes. The family loved to come up to the farm for vacations and to work alongside their parents.

In 1987, Clyde decided to take early retirement. A home was built on the Samsel farm near the original barn "My dad had died at 72. He had a stroke earlier at age 58 and another at 68 because of a lot of stress. I decided to retire from Johnson's to hopefully avoid the kind of stress he had been exposed to," Clyde said.

"The first thing we did when we retired was start planting trees for our neighbors," said Janet. "By 1973, the original trees we'd planted in back in 1952 were ready for the first thinning and we'd go out and cut down a couple [many] trees each day to sell for pulpwood," she said. It is a difficult choice whether to establish a tree farm at once or gradually, but the long-term investment it requires demands intergenerational cooperation. The success of Samsel can be attributed at least partially to the cooperation and goodwill of the family that runs it.

When the Sawmill in Wild Rose closed, the decision to vertically integrate into milling brought the retirement hobby-business into maturity as a financially sustainable operation. This was done by the promotion of labor to management. Current promotions are also allowing experimentation with new kinds of trees, and the development of a profitable educational industry as well.

When Jay left his Army career, he built his home near his parent's home on the farm to raise his children. The fourth generation of Samsels are being primed to continue and expand the business, even as the family business has grown to not only include the sawmill, but dry kilns, moulding facilities and a complete saw shop selling saws and logging tools.

manager might establish new plantations in more fertile grounds to grow new and more valuable crops, establish research and development centers to breed better seeds or make better tools, establish allied industries (such as milling, oil pressing, mining or timber production), open new markets through complex campaigns...these are the tasks that only the very best and most well trained employees are capable of undertaking. A franchise or subsidiary is not competing with the parent company, and any honor or resources gained by the worthy franchisee or subsidiary improves the worth of the parent company.

The successful maturation of an employee from simple laborer into franchisee or subsidiary motivates other employees to follow the same path. The glory and heights their managers achieve motivates the newer and less-trained laborers to diligently serve their managers – the laborers know that their managers are preparing them to achieve even greater honors. The laborers know their hard work will be rewarded magnificently.

A company's largess to its human labor is well rewarded. Human and animal labor are unique resources: the more that is invested to them, the greater the return to that investment. Managers should be empowered to reward their labor – or at least refer the reward to the company's leadership.

Summary of the objective of management

The objective of the manager is to improve resource efficiency, to induce more production with fewer resources. This process of industry requires many skills and sciences. Some are unique to the individual product that resources are being applied towards, but no matter the product of the industry, the skills and sciences required to make decisions on the applications of resources to the production are the same.

No matter the product of the farmer's industry, the product will have costs of goods associated with production and a value associated to the product of the industry. Because of this, the objective of the farmer to improve resource efficiency is easily translated into reducing the costs of production and increasing the value of the product, to use all their resources efficiently. This is why, to achieve their objective, the farmer must fully understand the process of their industry, understanding (in quantitative terms) all the resources required for their industry and the value of those resources and why farmer must also understand fully the value of the product of their industry and the basis of that value.

Understanding the process of their industry allows the farmer to improve the efficiency of their resources by using less resources to the same or greater effect. Understanding the basis of the value of the product of their industry allows farmers to gain more value (whether through direct application or through trade) from the product. Both understandings are comprehended by the term *resource management*, because both the product and the valuable goods required for production are resources to the farmer.

Training and encouraging labor to improve itself through self-management is one sure way of increasing industrial efficiency.

Jay now operates day-to-day operations so Clyde can focus on long-term strategy and educational services to the community on logging and land conservation, the promotion of the growing local lumber tree farming industry, and the promotion of the Ice Age National Trail, which crosses their land.

The market demands resources that are scarce and utile; the farmer produces resources, and should choose to produce things that are scarce and utile, adapting their production regularly to market demands; resources should be able to be used flexibly

When the objectives of efficiency are met, the farmer must turn attentions to applying their efficient production best: the farmer must meet market demands, and to do so must understand what those market demands are.

The market demands resources that are scarce and utile; the farmer produces resources, and should choose to produce things that are scarce and utile, adapting their production regularly to market demands. Resources should be able to be used flexibly.

This is not as complicated as it sounds: a farmer who finds a similar cost of growing beans and corn, for example, should grow beans if the beans are worth more to the market than the corn.

The market values resources in two ways, utility and scarcity. For a resource to be valuable, it must be both utile and scarce. A resource that is neither utile nor scarce is not very valuable. The multiplied product of utility and scarcity results in "market demand," a measure of the consumer's willingness to buy the resources by exchanging other resources for them.

Increase market demand by demonstrating greater utility, or by reducing production – however, most farmers do not produce enough market share or can keep others from producing their products to adequately reduce total production, and must demonstrate new uses for their agricultural goods or switch production. Different grades of commodity goods are actually different products: large and small apples have different demands

Market demand may be increased by the farmer in two ways. The farmer may demonstrate to the market more uses for their product, or by reducing their production to cause scarcity. However, since most products the farmer will produce can be produced easily by any of the countless other farmers selling to the market, unless the farmer acts in coordination with the other producers to simultaneously reduce production, the farmer is forced to increase demand for their product by demonstrating that their product is more utile than other similar products.

When corn was discovered to potentially answer for the production of ethanol at the turn of the 21st Century, this new use for corn increased market demand and raised prices so high that food riots rocked Mexico City. The same corn used for food and oil now had a new use, and not enough farmers had taken advantage of the higher market prices to meet demand. Eventually, enough farmers responded that there was no longer scarcity and prices fell to normal levels. The wise farmer does not attempt to influence the market's demand but only meet it: the cost of demonstrating a new use of a product is often not worth the expense.

An exception lies in the development of new markets or new products: when the consumer is not at all aware of the product, the farmer must demonstrate its use to them. [339]

[339] Such was the case with the great American agricultural scientist, George Washington Carver. Carver increased demand for the "new" products of peanuts and sweet potatoes by demonstrating their utility. Peanuts were cheap sources of edible, cosmetic and industrial oils, a potential source for energy (as would be later accepted by Dr. Diesel's engine); sweet potatoes,

Understanding market demand through the collection and statistical analysis of data

Understanding market demand requires data collection and statistical analysis to understand the relationship of various factors involved in the scarcity and utilization of their product. For simplicity, these relationships are usually presumed to be linear, but are in fact not linear. However, linear analysis facilitates a more easy correlative analysis.

The farmer who sells sunflower seeds should study what years the price was highest, and what factors resulted in those high prices. Did weather conspire to reduce supply and cause scarcity? Did laws change? They should also learn what impacts the utility of a product. Some varieties of sunflower have, usually, higher prices: the confection sunflower may have higher or lower prices than the oilseed sunflower; small apple demand is different than large apple demand, and the factors that determine utility are manifold.

Collecting data on the market is very difficult, but possible when the farmer is either willing to invest some time to contacting buyers and sellers or is able to rely on government or university researchers. In the United States, several agencies collect information on the market and the farmer is not unable to conduct analysis for lack of data. Where the farmer is not so fortunate, it may make sense to share such important data through trade associations or cooperatives.

If at a loss for information, the farmer may always undertake the following analysis: assess the total market value of a crop (or animal production) per acre, multiply it by the number of acres that the farmer believes they can sell before demand is exceeded and the cost to produce that crop. Choose the highest profit use of the land. In example, though meat snails produce more value per acre than beef cattle, the farmer cannot sell acres and acres of snail meat, and can sell acres and acres of cattle: in this case, the farmer would produce no more snails than they could sell, and apply the rest into cattle. Continuing the example further, they may find that the profit of producing wheat exceeds the profit of producing snails – even though snails earn more revenue per acre – and discontinue meat production entirely.

Trusting the market to pay most for what is most utile and scarce is the best path.

Agroecological resource management, or the dynamics of two farm managers

Farming is unique among all industries because the farmer is not responsible for at least some of the production. Weather, other organisms and any number of "natural" factors impact their industry. These uncontrollable factors are easily understood to be part of the ecology local to the farm: the farmer cannot ever enact a true agriculture, but must tolerate the agroecology that results from their attempts at agriculture.

Because there are two sources of management contributing to the production of value, the farmer may examine the cost of production as a factor of both their efforts and the efforts of the ecology. They may rely on the ecology to provide some goods and need not budget all the resources required for production. Exactly how much a farmer relies on the ecology to provide resources

besides providing high quality food, also provided dyes, construction materials and sweeteners. His advice for those who would follow in his footsteps? Besides a faith in God (he was a devoutly religious man who taught bible classes), "When you do the common things in life in an uncommon way, you will command the attention of the world."

depends on their skill, but every farmer is motivated to rely on the ecology as much as possible because it is cheaper to do so: the farmer need not pay for resources that the ecology provides.

The agroecology is, literally, of two "minds." The mind of the farmer is aware of the process of production and is able to adapt to the variability of the "mind" of nature. Because of Nature, the farmer is never without a partner in production. Yet it is a bad partnership because the farmer cannot communicate with Her and must simply adapt to Her actions. In example, if She provides more water (rain), the farmer must provide less irrigation; if She provides less water (rain), the farmer must provide more irrigation. Sometimes she decides to do things that seem very silly, and result in the devastation of crops and animals and there is nothing to be done about it.

Thus it can be said that the agroecosystem is composed of two interacting sources of management: a conscious management (undertaken by agriculturalists) and a preconscious management (undertaken by the rest of the natural ecological environment). In an unhealthy agroecology—as in an unhealthy animal mind—sometimes the preconscious and conscious undertake actions that are either are redundant or competitive. Redundancy or competition between the preconscious and conscious leads to a system that is at best inefficient and at worst unsustainable.

To bring the actions of the agriculturalist more in harmony with the actions of nature and sustain production longer at less cost, the agriculturalist must reduce the amount of redundant and competing actions between nature and themselves. And, since the farmer cannot change the nature of their ecology, they must change their own behavior.

This is best done by allowing nature to command the responsive reactions of the agriculturalist: while the conscious agriculturalist is able to perceive and adapt to the actions of the preconscious nature, the preconscious nature is unable to either perceive or adapt to the actions of the conscious agriculturalist. In other words, when the agriculturalist recognizes they are undertaking either redundant or competing actions against the natural ecology, the agriculturalist is able to weigh the benefits of such actions against the inefficiency of the redundancy or competition; the natural ecology undertakes no such scientific economic analysis.

This economic analysis requires assessing the industrial actions of both nature and the agriculturalist.

While the industrial actions of the agriculturalist are straightforwardly determined because the farmer chooses to do them, the interaction of the agriculturalist's actions with the natural (ecological) environment is not easily assessed because not all of the industrial actions of the ecological environment cannot even be directly measured. However, a minimum effect of the environment can be deduced:

It is known that a certain amount of total action is required for production: a bean will require a certain amount of water—whether it comes from the natural ecology in the form of rain, or by the agriculturalist in the form of irrigation. So, by observing the results of the interaction between the two sources of management, a minimum summation of the actions of the two sources of management is known: if the bean lives, there is certainly enough water for the bean to live; if the bean dies from dehydration, there is certainly not enough water for the bean to live. If the bean has lower than expected yields, it is because the amount of water was proportionately between sufficient amounts and deadly amounts. Because the actions of the agriculturalist are known and a minimum summation of action between the two sources of management is known, it is reasonable to deduce a minimum effect of the natural environment: if the agriculturalist provided no irrigation, the minimum amount of water provided by nature for the bean was sufficient for the bean to live, not live or struggle.

It is remarkable and very important to note that the actions of both the agriculturalist and nature can be broken down into the same unitary values of goods. These two sources of action interact. The agricultural management and natural ecological environment contribute definite amounts of valuable goods during a period of time. So long as the total amount of goods required for production is less than the total amount of goods provided by the combined efforts of the agriculturalist and nature during the period of production, there is a surplus of resources and the production can be sustained from the time of initiation (t_i) to the time of finish (t_f) of the period of production:

Sustainability of Production Units =

$$\frac{\textit{Goods Provided by Agriculturalist for Production}}{t_f - t_i} + \frac{\textit{Goods Provided by Environment for Production}}{t_f - t_i} - \frac{\textit{Goods Required to Sustain Productiont}}{t_f - t_i}$$

Here is the explanation of why a system of agroecology that favors natural industry to agricultural industry results in a reduced cost of production to the agriculturalist. This more "natural" system of agroecology is easily gained by reducing the redundant and competing actions provided by the agriculturalist (for example, if it is rains two acre-inches of water, the agriculturalist need not apply two acre-inches of water).

But, relying entirely on either the natural environment's actions or on the agriculturalist's actions is illogical: relying on nature is illogical because nature is unpredictable and therefore too risky to rely upon—also, usually, nature either does not provide enough resources for satisfactory yields or provides too many resources for satisfactory yields. Relying on the agriculturalist's actions is also unwise: doing so is often too expensive for the agriculturalist's budget. A combination of both agricultural and natural actions is required—but the agriculturalist should be careful to not undertake redundant or competing actions and reduce their necessary expenses to the minimum possible.

An example can be made by illustrating a human agriculturalist considering the sustainability of their pasture for their horse: the human wants to know if feeding their five horses grain is redundant when their horses have 50 acres to graze. It will be assumed, for the sake of simplicity, that grain and pasture provide the same nutrition: calories[340]. The entire agroecology will be simplified to the actions directly pertaining to feeding the horses calories:

The human provides 100lbs of corn grain every day, the pasture provides an unknown amount of food. Each one of the five horses requires 56 Mcals of food per day: when a 1,800 lb draft horse is worked 6-8 hours per day, it will consume approximately 56 Mcals (pages 83-86, 203, *Horse Nutrition: a Practical Guide* by H. Hintz, 1983). Thus, because the horses are not dead from starvation, they are receiving in total at least 280 Mcals daily (102,200 Mcals per year) from the combined efforts of the human and the pasture.

How much is the human giving and how much is the pasture giving? The human is providing 160 Mcals of corn grain daily—58,400 Mcals per year: there are approximately 1.6 Mcal per pound of

[340] Accounting for the full nutritional value of the pasture or the human-fed meals is possible (and, in real life, necessary), but for the sake of brevity, such accounting will not be provided in this example.

corn grain (pages 83-86, 203, *Horse Nutrition*). Subtracting the amount given by the human from their total need gets the minimum amount provided by the environment:

102,200 Mcals required per year
− 58,400 Mcals from the human
43,800 Mcals from the pasture.

43,800 Mcals, at least, are given by the pasture. But is this a sustainable system (can the production of horses be sustained during the time period examined)?

$$\frac{58{,}400\ Mcal\ grain\ from\ the\ Agriculturalist}{1\ year} + \frac{> 43{,}800\ Mcal\ pasture\ from\ the\ environment}{1\ year} - \frac{102{,}200\ Mcal\ required\ by\ the\ horses}{1\ year}$$

$$= > 0\ SPU$$

Any SPU greater than zero is sustainable for the term of the analysis.

Further experiment could be made to determine how much of the pasture is unconsumed, exactly how many calories are gained from the pasture, but this is not necessary: the amount of food provided by the human and environment in this case is sufficient for the maintenance of the horses and the human is not providing more resources than is potentially necessary. If the human was providing too much food, the amount of food provided by the human would be greater than the requirement of the horses and the human would not be allowing nature to feed the horses anything.

"Sufficient for the maintenance of the horses" does not imply that the human could not improve their efficiency: the human could certainly bring their contributions to the agroecology to a minimum by learning precisely how much food the pasture is providing (for example, the human could assess the pasture's yield to learn the amount of food provided by the ground and adjust their grain accordingly, or slowly reduce the amount of grain given to their horses until the horses begin to exhibit signs of starvation). "Sufficiency" in this case *does* imply that the 100 lbs of corn is sustainable during the term (one year) considered.

In a similar way, applying herbicide, pesticide or fertilizer to a field can be sustainable. However, it should be considered that the same or greater profit can be earned without the use of herbicide, pesticide or fertilizer: the same or greater yield may be earned with less resources. A system that has the agriculturalist provide more goods can be sustainable, but a method that requires the agriculturalist to provide less is more sustainable still.

By spending as few resources on production as possible, the farmer is able to undertake more production and earn a better return than had they invested their resources into resources the ecology was providing redundantly. An example would be a farmer who, with the savings they keep from not spending resources on pesticide, herbicide or fertilizer, invests in greater production capacity (land) and then earns a better return than had they spent their resources on pesticide, herbicide or fertilizer when the ecology was providing those services already.

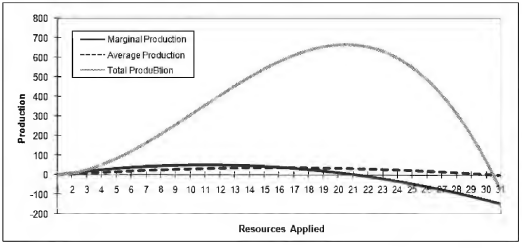
Two potential failures in a two-manager model: overapplication or underapplication of resources

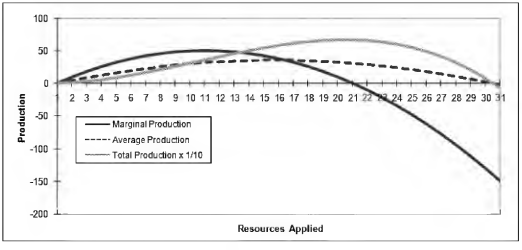
In this two-manager model, the farmer has two potential failures: overapplication of resources or underapplication of resources.

Determining whether resources underapplied or overapplied

Determining whether resources are overapplied or underapplied requires the generation of an understanding of the result of the farmer's application of a resource: how much production does it induce?

A hypothetical series of data (which will likely be typical) is presented on the following pages.





Data of the Graphs Presented on Next Page

Data of the Graphs

Resource	Marginal Production	Average Production	Total Production	Total Production x 1/10
0	0	0	0	0
1	10	5	10	1
2	18	9	28	3
3	26	13	53	5
4	32	17	85	9
5	38	20	123	12
6	42	24	165	16
7	46	26	210	21
8	48	29	258	26
9	50	31	308	31
10	50	33	358	36
11	50	34	407	41
12	48	35	455	46
13	46	36	501	50
14	42	36	543	54
15	38	36	580	58
16	32	36	612	61
17	26	35	638	64
18	18	35	656	66
19	10	33	665	67
20	0	32	665	67
21	-11	30	655	65
22	-22	28	633	63
23	-35	25	598	60
24	-48	22	550	55
25	-63	19	488	49
26	-78	15	410	41
27	-95	11	315	32
28	-112	7	203	20
29	-131	2	73	7
30	-150	-3	-78	-8

The first graph presents a farmer's data on resource use versus production, showing how much production is induced per resource. The second is the same data, but with the total production curve diminished to 1/10 scale to better show the relationship of the three curves. The marginal production curve shows the production when the given amount of resources are applied (if x amount of resources are applied, y will be produced), the average production curve shows the average of the previous set of marginal values to that point, and the total production curve shows the sum of the marginal production to that point of resource application.

The marginal production curve demonstrates that the addition of more resources induces first more production (when the curve is positive), and then less production (when the curve dips below the zero line). The marginal production curve is a measure of how much production is changing

because of that subsequent addition of resources. An example can be found with a lettuce plant receiving the resource of water. With no water, the lettuce will not grow. With some water, the lettuce will grow. With more water, the lettuce will grow better. With even more water, the lettuce begins to drown and will only grow a little bit. And more water than that will kill the lettuce plant: the plant begins to suffer from reduced production (less leaves) and then dies.

While the marginal production can be observed by the farmer, the other two curves are purely theoretical and are abstractions designed to aid the farmer's analysis: they present a measure of the marginal production curve's average rate of change (the average marginal production) and the total change of the marginal production (the total production). Going back to the lettuce example, the average production curve shows the average change in the production of lettuce: at that point of resource application, whether the lettuce is generally growing larger or smaller and how fast; the total production curve shows the size (total production) of the lettuce with the amount of resources provided to it.

These abstractions are important because knowing how much change is effected by the application of a resource allows the farmer to understand when to keep applying resources and when to stop applying resources.

The resource in question could be anything: labor, tillage, water, food...anything. Each marginal unit of resources (ex. unit of water or unit of food) is represented by a subsequent data point: the plant or animal in question gets 30 units of food or water for the length of the production process in this example. In no way is time represented on any of these curves: it is unknown from this graph whether those 30 units are given all at once or averaged out during the length of the production process. When comparing various resource application schemes (applying resources at once versus averaging them out), a separate analysis must be undertaken: the amount of resources applied is held constant and the frequency becomes represented by the integers on the horizontal axis (instead of the horizontal axis representing amounts of resources, it represents number of times the resource is applied). In either case, the shape of these curves will remain similar.

At first, with each addition of resources, the amount of product increases. But then, when the farmer has applied too much of that resource, the production suffers as if it had not received enough. To continue using the examples of water and labor, this demonstrates that a plant can get too much or too little water, and animals can get too much or too little food.

What is the best amount of resources to give to the product? The farmer does not want to reduce their production by applying too much, so they will never ever apply more resources beyond the point that they observe a decrease in production (at the maximum of the total production curve: at this point the total change from the application of the resources is still increasing). And the farmer also wants to ensure that their average rate of change in production is increasing, so the farmer will apply at least enough resources to achieve the midpoint of the total production curve (the point at which the average production begins to decline is this point).

In this hypothetical example, the logical amount of resources to apply to production lies between 13 units and 21 units.

Is there a more precise ideal amount of resources to apply? Some farmers would seek to have the most production possible, and would apply the greatest amount of resources to production within that logical range (in this case, 21 units). Some farmers do not want the risk of wasting any resources and will stop as soon as production begins to become logical (in this case, 13 units). How do farmers decide whether to be conservative or liberal with their resources? Analyze the cost of the resources in terms of return. If the cost of resources is so great that wasting even one unit of resources is greater than the value of the production between (in this case) 13 and 21 units, than it

would make sense to be niggardly with the resources. Few resources exist that are that valuable, and it is a good rule of thumb to attempt to maximize production by aiming for (in this case) 21 units.

It is important to remember that though a complete graph is presented here, the farmer will not (hopefully!) see the total production curve decline. The farmer, collecting data on their production, will only see when the total production begins to fall, and then react by reducing the resources applied.

With experience, the farmer will learn to anticipate how many resources are required for various products (for example, a farmer who grows beans every year readily knows when a bean is about to be flooded with water, but a farmer who has never grown beans before must undertake trials to learn the proper amount to water their crops).

It is necessary to undertake trials in production to learn the path of these curves. A series of tests should be designed, each applying gradually more resources to production. If the product is a kind of plant or fungus and the resource is water, several small plots can be planted next to each other, and each plot receiving one more unit of water than the last: the farmer needs then only to collect data on yield. Another test can be established for tillage, etc.

The farmer can establish tests for every resource they apply and improve their resource efficiency. If the product is animal, similar tests can be undertaken, but because animals are more variable from individual to individual than plants, it will either be necessary to undertake trials of large numbers of animals, or else undertake trials in several years consecutively. If the trial is to span several years, the farmer must keep very good track of what resources the environment provides so that they can factor out the effects of the environment: the farmer must undertake trials monitoring the *total* resources applied to production (the sum of both the farmer's and the environment's efforts).

But these resources all require labor for application, and therefore are functions of labor. Ensuring that resources are used efficiently begins with making sure that labor is efficient.

Resources are applied by labor; methods of assessing whether resources are applied efficiently in the industry of production

Resources are applied through labor, and this labor may be in the form of human, animal, mechanical or some combination of the three. In any case, there is inefficiency associated with the application of resources, and there will always be wasted resources. The manager who attempts to achieve no waste with the application of their resources has set themselves not only an impossible goal, but also an unprofitable one.

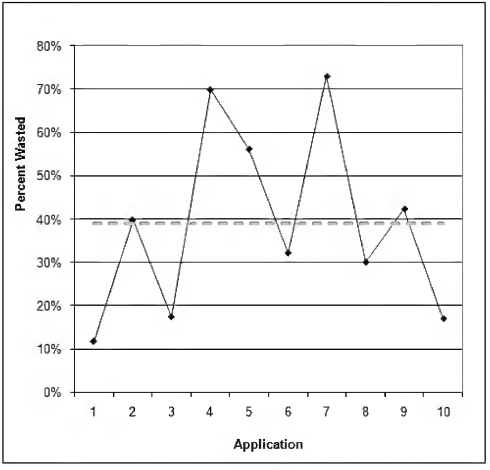
The theory of labor management became well developed in the late 20th Century mostly due to the heroic efforts of the American economist W. Edwards Deming (who is largely responsible for Japan's economic dominance during that time period). His books are highly suggested further reading, but the principles of his studies lay firmly in the foundations set by Adam Smith and David Ricardo. It is, after all, a simple thing to analyze the cost of resource conservation versus the cost of resource waste.

Demming understood that all labor actions can be viewed as success or failures according to how much resources they waste. Having quantified the success and failure of labor (and management), he could record the marginal production of each laborer against the resources provided to that laborer and use that data to understand why some laborers were more efficient than

others. From this information, he was able to (at less cost than the wasted resources) improve the resource efficiency of all the laborers.

Demming's principle tool was statistical analysis, a process by which he could not only identify the areas where waste was occurring, but the causes of that waste (by correlating his data against various factors). Rather than identify every individual variation from perfect efficiency, he looked at the average resource efficiency and attempted to understand the significant reasons for most of the variation. He understood that the cost of fixing insignificant problems was not worth the effort.

The following graph presents a farmer's data on their application of resources to a product: it is a measurement of the efficiency not of the resources, but of the application of the resources. Sometimes there is little waste (more product per application), sometimes there is much waste (less product per application). The farmer might be applying anything from water to food. The objective in this case is to improve the average efficiency of the application by reducing significant obstacles to efficiency. The average (mean) inefficiency has been marked by a dashed gray line, and is equal to 39% inefficiency, meaning that 39% of the resource is wasted in an average application.



Two questions should be asked: how is it determined whether an inefficiency is significant or insignificant, and how is it learned what the cost of improving the efficiency of resource application is?

Though the labor at times wastes more than 70% of the resource in question, at times they also waste only about 10%. Is a 39% average inefficiency significant? Is the 70% maximum inefficiency significant? The 10% minimum? Significance is arbitrary[341] and it will suffice here to say that significant variations it should effect the average efficiency enough to compensate the cost of undertaking the change required to fix it, so determining the significance of a factor requires understanding the costs of improving the efficiency. This philosophy leads to relative significance.

Relative Significance

An example is found by comparing the relative significance of an employee who, on average, accidently destroys 1% of every tomato transplant he is entrusted with (damage will be estimated at the value of $1 per tomato x 500 tomatoes per year = $500 per year), and the relative significance of an employee who, on average, accidently crashes a company tractor once every 10 years (damage will be estimated at the value of $5,000 / 10 years = $500 per year). Off hand, the tomato destroyer is causing just as much damage than the tractor crasher, and they are both relatively significant.

What is the cost of preventing these errors? If it would cost $1 per tomato transplant to prevent the damage (a total cost of $500 per year) to provide better transplant equipment, and $10 per month for insurance on the tractor (we'll assume that the accident is inevitable, but that it can be mitigated), the combined cost of damage minus prevention results in the tomato destroyer causing $500 damage - $500 prevention = $0 in damage, and the tractor crasher causing $500 damage – ($10 x 12 months x 10 years = $1,200) = ‹$700›. Thus, while the tomato destroyer is at least causing no net loss, the farmer has spent $1,200 mitigating the $500 damage the tractor crasher caused. We count, then, the tomato destroyer as less significant than the tractor crasher.

This does not mean that the tractor crasher caused more or less damage. Perhaps the tractor crashed into a barn, adding to the total damage! However, the significance of the tomato destroyer's error is that it can be affordably prevented: it happens infrequently enough that it can be easily prevented for no additional cost, whereas the tractor occurs too frequently to be effectively mitigated.

[341] A result is statistically significant if it is unlikely to be random. The amount of evidence required to accept that an event is unlikely to have arisen by chance is known as the significance level or critical p-value.

The significance level is usually denoted by the Greek symbol, α. Typically accepted levels of significance are 5% (0.05), 1% (0.01) and 0.1% (0.001). If a test of significance gives a p-value lower than the α-level, results are referred to as "statistically significant". The lower the significance level, the stronger the evidence required. Choosing level of significance is an arbitrary task. Interpreting data yields the significance: if something happens 5% of the time and α = 5%, this is not significant; when α = 5%, the data would have to occur 95% of the time. If something happens 99.9% of the time and the α = 0.1%, this is significant. If something happens 99% of the time and α = 0.1%, this is not significant.

Another example would be in two employees (a human and a machine) destroying tomatoes. If it costs nothing to prevent a human from destroying the tomatoes, but would cost $100 to prevent a machine from destroying tomatoes, the machine has a more significant error rate than the human.

More examples of relative significance.

An employee runs one hour late every day. If they run one hour late every day, it is unreasonable to suspect that every day something unusual happened. Catastrophes do not happen every day and the likelihood of a separate catastrophe occurring to cause the same delay every day is unlikely. It is more likely that there is a problem with the employee's process of preparing for work. Clearly, if the employee left for work one hour earlier, the employee would arrive on time. What is keeping the employee from leaving for work earlier? Is it that his wife is sick and because the farmer is not paying enough to allow her medical care and the employee must take care of her himself? Is it that he is unmotivated to come to work? Is it that the bus schedule prevents a timely arrival? Inquiry would detect the cause of the problem and help the farmer identify solutions. If the employee can induce $20 of production per hour to the farmer, the farmer may spend up to $20 on the solution and still come out ahead.

For example, if the employee's wife is sick and it would cost $10 to provide medical coverage for her, the farmer has earned $10 by spending $10. The employee will also then work all the harder for the farmer's kindness. If the employee is unmotivated, the farmer can learn why: is it that the employee is overworked, underpaid, abused by a fellow employee or manager, or lazy? Nothing will help a lazy employee, but such employees are rare: most employees are willing to work. Identifying the cause of the problem will show the farmer both the cost of fixing the problem and the cost of tolerating the problem.

But what if the inefficiency is due to extraordinary circumstances? Perhaps the employee has a second job that works them late at night, or perhaps the employee got sick. Perhaps the employee makes more mistakes right before lunchtime and before quitting time than during the rest of the day combined? Again, inquiry will show the farmer the causes of these extraordinary circumstances, the costs associated with them and the costs of fixing them. If the employee is sick and will waste $100 of resources until they get better, but it would cost only $50 to provide paid medical leave for them to get better, it is clear that the farmer should repair and "fix" the broken employee quicker than they could do on their own. If the employee will waste $100 of resources because they are forced to work an extra job, but it would cost only $20 to pay the employee enough to not need another job, the farmer would earn $80 more by raising the pay of the labor.

If a seed drill wastes less than 1% of the seed except on wet, muddy days (when it wastes 90% of the seed), clearly the cost of waiting for the mud to clear is worth the delay in planting. The farmer must be vigilant in collecting data to empower themselves if they are to be able to analyze any inefficiency on their farm.

The error of ending the employment of inefficient employees: lost costs in training rarely overcompensated by future hire's improved efficiency, and likelihood of a more efficient hire is small: efficiency is gained through training, not luck. Demoralization also results

But why not just terminate the employee's employment and hire someone else who is, perhaps, more efficient?

Some employers will terminate an inefficient employee and hope to gain a better-performing employee in the next hiring process. However, the likelihood of obtaining a better employee is poor,

and the investment made into the existing employee is considerable. The lost costs of training must be overcompensated by the new hire's efficiency, and this rarely occurs. Efficiency is gained through training, not luck.

Demoralization of the termination must also be accounted for: when any employee is terminated, demoralization is reflected in some temporary or permanent loss of productivity. The opposite is also true: when employees are retained and the investment made into them is valued, they will invest more into their training and become more efficient.

Some farmers are quick to fire "bad" employees. This is usually a poor decision: it costs more money to hire and train a new employee than it does to "fix" a bad employee. Added to the costs of hiring and training are the opportunity costs of retaining a "bad" employee: trained employees waste less resources than new ones. It is the same with employees as it is with machines or animals: it costs more to replace than to repair and maintain. The farmer will always lose by this game of hiring and terminating: not only is the probability of finding a better employee low, but the investment the farmer has made into the hiring and training of the employee is irretrievably lost when the employee is terminated. No, the wise farmer retains employees and helps them to become more efficient.

Non-relative significance

Sometimes, all errors will be of similar relative significance! To avoid the pitfalls of relative significance, the manager must establish limits on how much error can and will be tolerated. The first step is to analyzing data is to understand whether the maximum and minimum inefficiencies are exceptional or not. This directs the manager in their work.

The manager's job of innovating tools to increase efficiency

The manager's job is to identify inefficiency and to reduce the inefficiency in such a way as to maximize profit for the firm. The manager is limited only by their ingenuity, but even this is no limitation when the full causes and effects of the resource inefficiency are learned: if the mud sticks to the seed drill, the manager can devise an implement to clear the mud before it sticks to the seed drill; if the employee's wife is sick, the manager can help the husband care for his wife.

If the labor is inefficient at applying water because the pipeline is leaking in places and the cost of repairing the pipeline is cheaper than the cost of the water, it makes much sense to improve efficiency by repairing the pipe. If the pipe costs more to repair than the water is worth, it might make better sense to plant a few things along the pipe: the slight cost of tending a spread-out garden is less than the cost of the water saved and the farmer comes out of the crisis with a profit.

Countless examples present themselves to the farmer every day – if the farmer is aware (through their data collection) of them.

For the manager unskilled in statistical mathematics: approximate standard deviation by separating 25% of the data to find statistically significant industrial errors

The farmer may determine whether inefficiency is due to extraordinary or ordinary circumstances by applying statistical analysis to the data and observing outlying and extraordinary data.

The farmer who is unskilled at mathematics may approximate the analysis by first observing the mean and taking the standard deviation from the mean: this will illustrate to them all the points that are more likely to be extraordinary. If the farmer is unable to take the standard deviation, they may approximate further by placing an arbitrary division to the data that separates roughly 25% of the most inefficient data[342]. The purpose of the line is to separate those data points which are most likely to be exceptional from those which are more likely to be ordinary, and so little exactness is required.

This helps focus the attention of the manager on those errors which are abnormally beyond the standards of acceptability.

Such a line has been drawn on the following graph, along with a theoretical improvement to the average inefficiency when those extraordinary data are corrected by actions from the manager: if the errors above 1 standard deviation (the top dotted line) are brought to equal the average inefficiency, the average inefficiency will improve 9% (from the grey dashed line to the black dashed line).

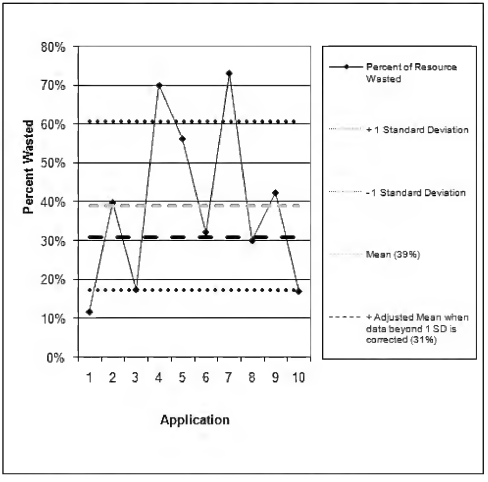
[342] While in a normal distribution, 68.20% of the data will be "normal," or within 1 standard deviation, we approximate with 50% (2 x 25%) because the math is much easier to do, this section being geared towards those needing simplification due to lack of skill or lack of computing tools. Those farmers who wish to approximate closer should extend, instead of 25% from the average, 34.10% from the average.

An observation is rarely more than a few standard deviations away from the mean. Chebyshev's statistical rule of inequality states that, for all distributions for which the standard deviation is defined, at least 50% of the values are within √2 standard deviations from the mean, at least 75% of the values are within 2 standard deviations from the mean, at least 89% of the values are within 3 standard deviations from the mean, at least 94% of the values are within 4 standard deviations from the mean, at least 96% of the values are within 5 standard deviations from the mean, and at least 97% of the values are within 6 standard deviations from the mean. And in general at least (1 - 1/k2) x 100% of the values are within k standard deviations from the mean.

Those wishing to be even more accurate should calculate the exact standard deviation:

$$s = \sqrt{\frac{\Sigma(X - M)^2}{N}}$$

The standard deviation (s) is found by subtracting the mean (M) from all the numbers (X), taking the square of the difference, dividing that difference by the number of numbers and then taking the square root.



Interpreting data requires correlative analysis

Once the extraordinary data is observed (in this case, applications 4 and 7 on the inefficient side, and applications 1 and 10 on the efficient side), the causes for those extraordinary data can be understood by examining the factors that similarly influence those data. The best data must be examined as closely as the worst: both good and bad will demonstrate the same factors influencing production. This process of understanding which factors are most responsible for data is called *correlative analysis*. Two potential scenarios will be given before the process of correlative analysis is described.

In one scenario, the data may be seen as tracking individual laborers through a similar process of resource application, in example, hand seeding in a greenhouse. Why would laborers 4 and 7 be exceptionally bad at this process? Upon inquiry, it might be discovered that they have abnormally large fingers and can't grasp the seeds as well as those with smaller fingers (laborers 1 and 10). A solution is to provide better tools (such as funnels or dibbles) that will improve the dexterity of the large fingered labor.

In another scenario, the data may be seen as tracking similar labor through various applications, in example, delivering produce (the efficiency measures the amount of deliveries on time, in this case, before 8:30 PM). What causes deliveries to be so late on those days when deliveries occur extraordinarily late? Why would so many of the deliveries be after 8:30PM when the same labor on other days is able to deliver more than 88% on time? Perhaps those days when it is worse are the heaviest traffic days of the week (i.e. Monday and Friday), and the days when it is best are the days with the least traffic (i.e. Sunday and Saturday, applications 1 and 10). A solution is to deliver on days with less traffic.

Inquiry must guide the farmer to understanding the connections between data and correlative analysis must guide the farmer's inquiry. The farmer does not know in advance (as the reader does with these two examples) why 4 and 7 are inefficient and 1 and 10 are efficient.

To correlate data requires advanced statistical training, but the process may be approximated by a novice with some success. There are two methods of correlative analysis: experimental and observational. The first method requires establishing experiments to control (factor by factor) all the factors that might influence the outcome (in this case, resource application) until the factor or factors that most influence the outcome are discovered. The second requires observing data of many factors and identifying (through logic or mathematics) which one or ones might be most responsible. Because of the semi-random nature of farm data, the farmer usually must rely on logic or mathematics to help them undertake correlative analysis, though it is possible to undertake experimental data and analyze it.

Correlation Analysis Methods

The farmer begins their analysis by listing all potential factors that might influence the outcome (in this case, resource application efficiency) and collects data on each of those factors. Using the two scenarios before, two examples will be given.

If the farmer is analyzing the efficiency of their labor against other labor (such as in the seeding example), they will collect data on the labor itself. The environment is believed by the farmer to be constant: all labor is using the same seeds and same equipment on the same soil. The farmer needs only understand how the labor is interacting with the environment, so the farmer will first discover all the factors that might influence the labor's interaction with their environment. This is usually limited to data on their ability to undertake the task: their ability to perceive the environment (eyesight, hearing, tactile capacity, etc.), their understanding of the task (training, years of practice, etc.), their health (including whether they are rested, well fed, hydrated, etc.), and their ability to manipulate the tools and resources required (here the farmer would discover that some of the labor is unable to grasp the seeds well). If all labor is equally able to undertake the task, the farmer will then discover all the factors that influence their willingness to undertake the task (perhaps they are not paid enough, perhaps they are abused by their management, perhaps the management has provided disincentives to efficiency with bad directives[343], perhaps they or their

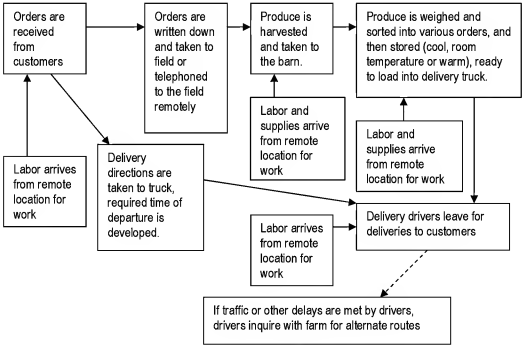
[343] Countless examples may be provided of inefficiency caused by bad management. Artificial deadlines might be established (the manager tells the labor to finish a job before a certain time even though there is no logical basis for it, in example, if labor is told to finish harvesting pumpkins by 3PM, they will be uncareful and either leave some behind and damage the ones they don't...and the pumpkins they might not have harvested could have been left for another day because the delivery of

spouse or families are sick, etc.). Countless lines of inquiry and factors might be listed, and each are dependent upon the situation. The farmer must use their familiarity of the process of resource application guide their data collection.

If the farmer is analyzing the efficiency of their labor in changing circumstances (such as in the second scenario), the farmer must again rely on their familiarity with the process of resource application to guide their inquiry. What influences delivery time? Traffic certainly would be at the top of the list for most farmers. What else might influence delivery time? Is the produce loaded into the delivery truck in time to make the deliveries? Are the drivers well rested or needing regular breaks during their shift? Are directions to the various deliveries difficult to follow?

It is useful to create a flow chart to track all the factors that influence resource application so that the farmer can better track all the factors that require observation. An example flow chart for a farm that provides home delivery service and custom harvests every week is here provided:

pumpkins was not scheduled for a week), quotas might be established (labor might be told [either directly through orders or indirectly through commission-based pay] to sell so many gallons of milk per month or else they'll be fired, so they'll sell milk below market price). Under no circumstances should labor performance be linked to pay. Labor performance is the responsibility of the management and ownership. Compensation methods to increase efficiency is discussed later. Another common mistake is for management to terrorize or abuse employees – either directly, or indirectly through unreasonable directives (such as those directives that require the employee to do not only the work they were hired to do, but extra work without any extra pay: some farms require labor to not only harvest and tend the fields, but to interact with customers...and pay only for the field work. It is no wonder when the labor is rude to customers!). Documentation is also an impediment to labor: data collection is the job of management or of specialized labor. Excessive precision is also an impediment to labor: some farms will fire employees if they damage produce more than twice in three years, or miscount change to customers more than three times ever, or late more than once. A wise management decision would be to improve the harvest equipment (more cushioning in the harvest boxes), provide automatic change counters, or to help the employee arrive on time by not scheduling late night shifts before early morning shifts. Countless examples might be provided, but won't be.



The farmer can clearly see that there are usually 10 and sometimes 11 points at which inefficiency can occur before the delivery drivers leave for deliveries to customers (there would be more if the farmer was more precise: there should be arrows indicating the supply of electricity, the supply of water and the supply of other raw materials as well, but for the sake of simplicity, none of these – or other factors – were included). Because inefficiency can never be eliminated, the more points at which inefficiency can occur, the more points at which inefficiency will occur. This does not mean that there must necessarily be a compounding effect: just because the directions are delivered to the truck late does not mean that the driver will leave late: the produce may not yet even be harvested. However, it does mean that there are points at which inefficiency is tolerated less: it is more important to receive orders in time to harvest them than it is to provide directions in time for the truck to leave (the truck can always call the farm for directions).

The farmer can then list all the factors that might affect efficiency at each of those points and collect data on those factors for logical or mathematical analysis (or perform experiments to gain better understandings). Each arrow represents the impact of countless factors against and for efficiency.

Perhaps the easiest way to improve efficiency is to reduce the number of points at which inefficiency can occur (reduce the number of arrows by eliminating steps). If the labor did not need to arrive remotely (if the labor lived on site), this would remove 4 opportunities for inefficiency. Family farms that live on site are more efficient than farms that rely on labor coming from distant (and sometimes international) places. Recognizing the source of this inefficiency, farms that rely on migrant labor are transitioning into using non-migratory labor by providing long-term homes and salaried positions for the once-migrant populations of workers, building Company Towns (even complete with schools!). In doing so, they not only better secure their labor, but earn more work for

the pay they provide and starve their less-adapted competition of the resources (labor) necessary for their industry.

This is the motivation of farms to become entirely independent and develop not only their own sources of power, but their own supply of raw materials and tools required for production.

But there are only so many ways in which the farmer can remove steps required to induce production and so the farmer who would manage the application of their resources well must always be looking at ways to improve that application.

When the farmer has data on each of the factors that might influence the resource application, the farmer puts them side-by-side with their data on the resource application itself. The farmer might notice that laborers 4 and 7 have the largest fingers and that laborers 1 and 10 have the smallest and through logic determine that there might be a connection between the factor of finger size and seed waste...which is tested by improving the "finger size" of laborers 4 and 7 with tools – if the problem is corrected, the farmer's presumption was correct and (if laborers 4 and 7 become as efficient as the average of all the other laborers) the average inefficiency is reduced to 31% from 39% (if they become more efficient because of their tools, the farmer will see even better average efficiency).

But how did the farmer know it was finger size and not, for example, the sex of the labor, the training of the labor or any other factor? The farmer will take notice of those factors that best match the data: those which most closely correlate – either directly and positively (by going "up" when the data goes "up" and "down" when the data goes "down") or indirectly and negatively (by going "up" when the data goes "down" and going "down" when the data goes "up") – are the factors that are most likely to be responsible for the changes in the data.

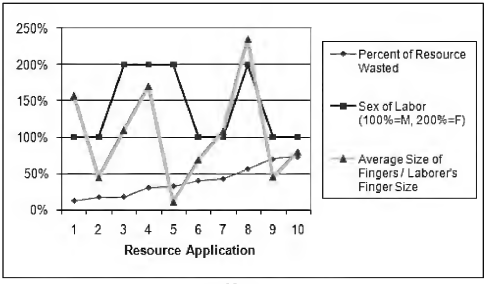
The closeness by which the data of a factor and the data of resource application match – their *correlation* – results in a ratio. The ratio (which will be between -1 and +1) is a measurement that numerically demonstrates to the farmer what is most likely to impact production. Values that are closest to -1 or +1 are most likely impacting production.

The correlation of any two data sets may be calculated with the following equation:

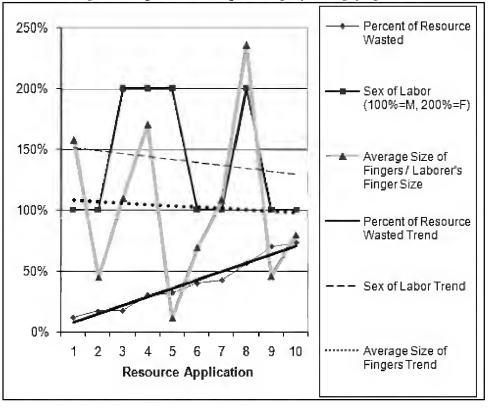
$$\textbf{\textit{Correlation of data sets X and Y}} = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

Roughly put into words, this calculation requires the farmer to take the sum (signified by Sigma, Σ) of: data set x's variance from data set x's mean ("mean" or "average" is signified by the x or y with a bar on top) multiplied by data set y's variance from data set y's mean. Then, this sum is divided by the square root of: the squared sum of data set x's variance from data set x's mean multiplied by the squared sum of data set y's variance from data set y's mean. It is a measurement of the interaction between two sets of data as they vary from their means.

The following is an example of applying correlation to determine whether the sex of the labor or the size of their fingers (or either) most impacts the amount of resources (seeds) wasted when seeding.



Note:
Finger size is presented as a percentage of average finger size



The data has been resorted so that the laborers with the greatest efficiency are listed first and those with the least efficiency are listed last. This has been done to aid visual analysis. To further

aid visual analysis, a line has been drawn through each data set to approximate their trend over the resource applications. It can be seen that as the number of men increases (the linear trend line of the sex of the labor falls), the greater the inefficiency. Also, it can be seen that as the finger size of the laborers generally increases (the linear trend line of the finger size falls), inefficiency increases too. The amateur can, without mathematical precision, understand that men have larger fingers than women and that this leads to inefficiency.

But how much of the inefficiency is due to the finger size? How much is due to the sex of the laborer? The farmer will take the correlation of both factors and discover that there is a -20% correlation between sex and inefficiency, and a 0% correlation between finger size and inefficiency. It does not matter how the data is presented (in what order) for mathematical analysis.

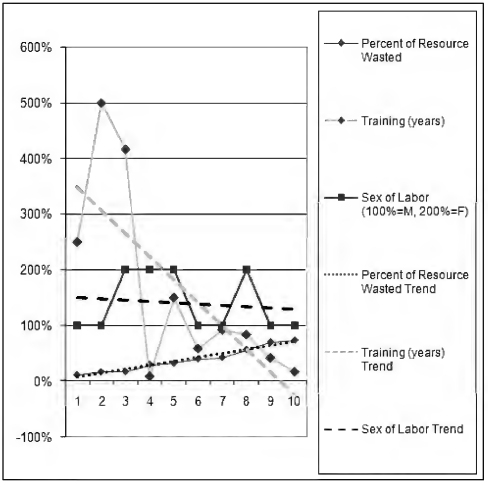
Most farmers are content with accepting that a factor is a major one if it has a correlation of more than +.25 (25%) or less than -.25, (-25%) but other farmers require more definitive proof and require a value more than +.75 (75%) and less than -.75 (-75%). A true correlation (-1 or +1 or, in percentages, +100% or -100%) is very rare.

In this example, it turns out that finger size matters not at all, and that the sex of the labor might matter some. So the farmer must ask, why would the women be better at seeding, if not for their finger size?

The farmer begins to analyze the various aspects of their women laborers. What is special about them that they are better than their male counterparts?

The farmer should be thankful that they do not need to do much thinking. Due to correlative analysis, all factors that might influence production are already understood and await only analysis. Through scientific analysis, the farmer is able to see which factors most influence resource application. The farmer is then empowered to improve their efficiency by making necessary changes. Since finger size is not a major influence to the resource efficiency, and the sex of a laborer is not a major influence (even if the farmer were incapable of understanding that to hire only women would not find the solution to their problems, the farmer is able to see that the correlation between sex and efficiency is not acceptably high), some other factor is at play.

One by one, each factor influencing production is correlated against the inefficiency of the resources until the best correlations are found. After trying dozens of factors, the farmer attempts to correlate the training (experience) of their labor against inefficiency:



The farmer has calculated a very strong -71% correlation between training and inefficiency (and notices that the female laborers have more training than their male counterparts. The farmer also understands that this sex is no reason why the women are more trained than the men because there is only a 1.4% correlation between sex and training: there is no reason why the women are more trained than the men because it is almost a 0% correlation). It is very likely that with more training, the farmer's least efficient laborers will become better. The farmer can then assess whether or not it is worth the return to speed the training of the least efficient laborers with a training program by assessing the cost of training the laborers against the return of greater efficiency. Sometimes the farmer will decide that it is not worth the expense and will allow the laborers to gradually gain experience over time. Other times, the farmer will decide that greater efficiency pays for itself. How much more training is required depends on the farmer's tolerance for inefficiency. It can be seen that after just one year of training, laborers will generally perform at or above the average resource efficiency, but that the return to additional training after one year is slow.

The farmer can also apply the mathematical analysis discussed previously (on whether resources – in this case, training – is being over or under applied to the production – in this case, laborers) to learn whether or not training is logical.

With statistical analysis, the farmer can make sense of the enormous amount of data they collect. Those factors with the highest correlation to production data are kept for direct study, those that have low correlation are kept to be compared to other low-correlation factors to see if, together, they have a higher correlation than separately: the farmer might track traffic data against delivery time and notice that on days 4 and 7 there was the greatest traffic and on days 1 and 10 there was the least – and discover that on days 4 and 7 the produce was late being harvested and loaded on to the truck. Both have the same correlation to the inefficiency, but on those days when the produce was later and the traffic was heavier, the delivery was later; those days when the produce was harvested earlier and the traffic was lighter, the deliver was earlier. Together, they impact the resource efficiency more than alone.

This analysis is easily applied to all methods of resource application, including human, mechanical and animal. Are equids better at applying force to the plow than bovines? Is a mechanical bean thresher more efficient than a human? Is it a waste of resources to kill weeds when, upon analysis, it can be shown that it is more profitable to tolerate weeds and till in the aisles?

Maintaining, Replacing and Acquiring Labor Resources: Mechanical, Animal and Human

Once the farmer understands whether resources are underapplied or overapplied and how to improve the efficiency of the application of those resources, it is important for the farmer to understand how to maintain, replace and acquire labor resources.

It was one of Jethro Tull's chief complaints that his labor was as much an enemy to him as a friend. Though not every farmer suffers from labor that kills horses or steals crops, every farmer should be afraid of labor that (even if not purposefully) will damage their operation. Malicious labor is the result of improper maintenance: just as a machine will become dangerous and destroy the farmer's property and person if improperly maintained, just as an animal will become vicious or unintentionally dangerous if improperly maintained, so too will human labor.

It is the natural inclination of all creatures to be free. Yet the act of domestication is a highly natural one and results from the natural ability of all creatures to comprehend the action of trading. Whether the farmer is domesticating a plant or an animal or a human, the act of domestication is always unfinished. The partnership that arises from the trade of resources must be reestablished continuously. It is natural for a creature to be free, but more natural still for them to serve a good master. It is no different with human labor.

Some ants are especially good at domestication and rely entirely upon their domesticated draft labor for their survival. The comparatively primitive domestication of fungus, aphids or mealy bugs only begins to shed light on the profound nature of a domestic relationship for ants. Amazon ants (also known as "samurai" ants) have only two castes: royalty (breeders) and soldiers. The purpose of the soldiers is not to care for the royalty, but to capture and domesticate ants from nearby nests (and other creatures that are suited to the work) who will then care for the royalty. These captives are taken from their families when they are very young, and come to believe their new multiracial nest is their home so dearly that they can be led to attack the nest of their biological parents. They come to believe that the multiracial nest is their home because they are treated like family there.

So too can even human beings be domesticated and taught to serve. For one human to die for another in war, for one human to do work diligently and carefully for another, for one human to give their life's strength requires only that they be treated like family.

This is also the purpose of the management of a company: to care for the needs of the labor. Management is not only concerned with the care of the company (by ensuring resource efficiency) but also with the care of the labor. Their physical and psychological needs must be met. They must receive compensation in resources, in praise, and in the case of humans alone, in honor.

Compensation by Resources

A "manager" is a "breadgiver." "Breadgiver" a word that became in modern English "Lord" or "Master" ("Master" came from "My Sire," ("Sire" is another word for "Lord:" ma [my] sir [Sire]. Refer also to the history of the French "Monsieur," "my Lord"). In the sense that the human laborer looks to the manager for training and education – behavior typically expressed in childhood towards a mother or father – the human laborer necessarily looks to their manager as a kind of mother or father.

In all ways is the manager a Master of the labor. The history of this word is essential to understanding the manager's role to the labor: they are a father or mother to their workers. Though times have changed little from the Feudal age of Jethro Tull when Lords commanded their "Knights" (a word that means, "boys" or "children") and obeyed their King or Queen, times have changed enough to warrant a renewed explanation of the obligations of management (nobility) to both their labor (commons) and to their company's ownership and interests (King or Queen).

By Jethro Tull's time, the power of the Nobility was weakened and the first flowers of Democracy and Republicanism in Europe since ancient times were budding. 130 years before the publication of the First Edition of the *Horse Hoeing Husbandry*, the first Republican Covenant was chartered in what is today Massachusetts, and by the time of the Second Edition, the first rumors of an English colonial war were whispered. Just 35 years afterwards, America would define its Independence from England.

The reason for the erosion of the power of the nobility in Jethro Tull's time was for the nobility not upholding their obligations to the commons and the King or Queen. And, just as Empires have fallen in the past, so too can a modern farm fall for a corrupted management. If the management (nobility) does not serve both the labor (commons) and the ownership or interests (King or Queen) of the company, the labor will stop serving the interests of the company and will, upon frequent occasion, even attack or attempt to destroy the company through theft, vandalism or other hatred.

Jethro Tull was a minor noble of the English aristocracy, and because his labor attacked him, it means that, though he was a good farmer, he was also a bad noble. Tull describes the circumstances leading to his war against his labor in detail in his introductions, but it suffices to remember here that he sought to reduce or eliminate his dependence upon them. Though nothing justifies the violence they perpetuated against him, faced with a threat to their existence, it is little wonder that they should have counterattacked Tull.

Whenever companies mechanize labor to reduce or eliminate their reliance upon human labor, the machines and company face attacks – if not of the violent physical kind, then of the more pacific strike or protest. Why would the employees not hold the interests of the company at heart and be glad at the improve resource efficiency of the machines (their new workmates)? Instead of retaining and reassigning the valuable human labor resources, the companies typically will retire or eliminate the human labor upon the acquisition of equivalent mechanical replacements.

But why would a company retire or eliminate such a valuable resource as a human laborer?

The amount of money and other resources sunk into that person's training is typically undervalued by a company and, because the employees cannot trust the company to continue serving their needs, they cease to continue serving the company's needs. A wise manager would not throw out a valuable machine when it could be disassembled and made into something new and equally (or more) valuable to the company; a wise manager does not retire or eliminate any resource. Resources are precious, and once acquired must be retained to the limit of their profitable employment.

Human labor is no less precious. Entirely interchangeable, retrainable and nonspecialized, humans are capable – at a moment's notice – of learning an entirely new job and performing it tolerably well. No member of a company or nation is any more important than any other. In companies and nations there are roles that are more important, but no one person is (significantly) better able to fulfill those positions than any other person.

For a company (or nation) to survive requires not only equality in compensation among all people belonging to that company (or nation), but the filial love and care of all members of the company (or nation) by the other members. All laborers should be compensated by resources equally – and must share the burdens of the company equally. Just as in a body the hands receive just as much nutrients as the feet, head or heart, so too is every employee equally important to the company. The janitor must receive the same compensation as the accountant as the harvester as the delivery driver. Without one doing their job well, the consumer never gets the product.

Jethro Tull, upon mechanization, undervalued his human labor and did not care for their needs. Though he earned more money by abandoning the human labor for machine labor, he would have earned more money still by retraining his human labor to use the machines and expanded his operations either through franchise or through direct ownership.

It is always more profitable for the farmer to maintain and repair labor (mechanical, animal or human) than it is to replace labor...even if that labor was just acquired. And, because labor is the greatest and most irreversible investment that a farmer can make (every dollar paid to labor can never be refunded: once the exchange of money for labor has been made, it can never be unmade), the farmer is obligated to ensure that the labor is not only ready for work, but able to provide as much work in exchange for money as possible...even if the skills they are equipped with are outdated. Rather than encourage the farmer to invest less into their labor, the irreversible nature of the labor investment (when combined with the higher cost of replacement versus repair and maintenance and the high return to investment) encourages the farmer to invest more into their labor.

The most important act of maintenance is training and retraining.

In the first volume of the 2001 journal of *Ecological Indicators* (pages 37-47), Doctors Jennie Popp, Dana Hoag and D. Eric Hyatt define and assess the farmer's motivation to sustain production in their article, *Sustainability Indicies with Multiple Objectives*. The doctors are quick to identify that the rate which resources replenish within an industry is the factor that principally influences the amount production can be sustainably induced above natural levels: this is the primary factor influencing costs of production. They identified that the inverse relationship between the amount of natural resources available to industry and the costs of production is due to the higher costs of maintenance and repair of resources when the natural ability of the resources to self-maintain or repair is little.

What the Doctors did not discuss was the diminishing cost of maintaining production when resources are replenished promptly, that it costs more to repair than it does to maintain, nor did their index of sustainability measure the cost of maintenance over time.

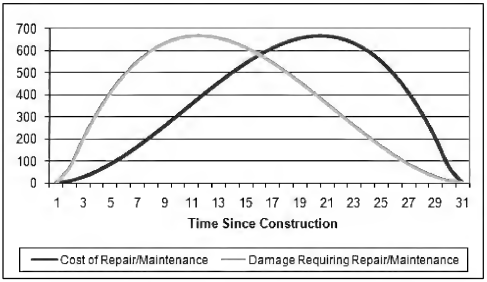
For the convenience of the reader's reference, the calculation used to estimate the sustainability of production is reprinted here:

Sustainability of Production Units =

$$\frac{\textit{Goods Provided by Agriculturalist for Production}}{t_f - t_i} + \frac{\textit{Goods Provided by Environment for Production}}{t_f - t_i} - \frac{\textit{Goods Required to Sustain Productiont}}{t_f - t_i}$$

When the agriculturalist requires production to be sustained over a long period of time without contributing more resources, the agriculturalist necessarily requires that either the environment contribute more resources (which the agriculturalist cannot do because the environment's contributions lie beyond the agriculturalist's control) or else that the goods required for production is reduced (production is reduced).

Industries that require fewer resources are more easily sustained over a long period of time. The longer the term that production is sustained, the more costly that production will be for the agriculturalist, that many little acts of maintenance are cheaper than a few major acts of repair. Few examples present themselves to illustrate this fact more willingly than that of road repair and maintenance. An example is illustrated by a hypothetical graph:



A road produces the utility of transportation. When a road is first constructed by the farmer, the costs of maintenance are low (the cost of maintenance may be measured by the area under the curve): cracks may sealed easily, missing stonework can be easily replaced. As a road goes longer and longer without maintenance, it becomes more and more costly to repair, it becomes more costly to regain the utility of transportation lost to damage: soon the entire road must be relaid. At this point the road is not yet done falling to pieces and will become, instead of a very poorly maintained paved road, an excellently maintained unpaved road that requires the little bit of maintenance

required to clear it of debris (the remnants of pavement). This is the point when the cost of repair/maintenance curve is at its highest. Left a little longer, the unpaved road will clear itself of these obstacles and the road will require no maintenance again: it has been remade into an unpaved road (this is the second minimum of the two curves).

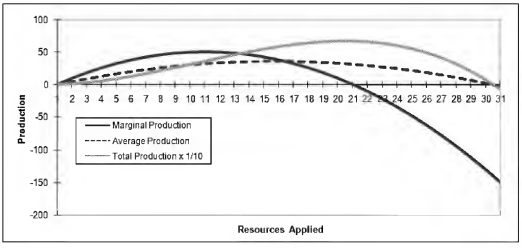
This is not to suggest that the road won't require maintenance soon – the unpaved road will soon require rescraping and clearing as the grasses and other vegetation reclaims for nature the roadways of humanity. But this cyclical nature of maintenance costs is illustrated by a reconvergence of the costs of repair and the damage requiring maintenance to zero.

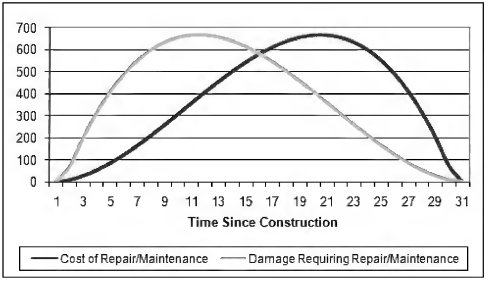
This argument, that it costs less to maintain than to repair or remake, is the same one that is used to justify the generous budgets of public transportation departments: at a public meeting, you will chance to hear the Departments of Transportation and other utilities threaten the public, saying that if the public thinks their budget is excessively expensive now, just wait a few years with inadequate funding and you'll see their requirements increase even higher! It is the same argument used to justify the funding of the schools, libraries and prisons (that maintaining a citizen's adherence to law through schooling and discipline is cheaper than repairing the citizen in prison). It is the same argument used to justify defensive war (stopping the aggressors before they pillage is cheaper than repairing the damage they cause), post-war reconstruction (helping your enemy stand back up as your friend after you knock them down is cheaper than occupying them only to fight them again in the future) or any action of production and maintenance.

Indeed, it justifies the maintenance of labor before the repair of labor is required. Whether a machine needs an oil change or a new coat of paint, or an animal requires a veterinarian, or a human requires a doctor, labor is cheaper to maintain than to repair, remake or replace. It is far cheaper to pay labor a living wage than to repair the damage caused by labor (purposefully or unpurposefully) when they are not properly maintained.

But how much should the farmer pay their human labor to ensure that they are well maintained?

The proper amount to pay labor to ensure they are well maintained may be learned mathematically from data collected by examining the relationship between the cost of maintenance/repair and the amount of maintenance/repair required. Since the farmer should never have the chance to undertake such data collection (it is unethical and unprofitable to push labor to the point of breaking), it is theoretical to say that the curves presented before resemble the costs and production of industry. For the convenience of the reader, the graph has been reproduced here:





The reason for the presumed similarity is because repair and maintenance is itself an act of production and obeys the same laws that govern all acts of production. If it is true in all other circumstances that production and maintenance resembles the production functions presented before, it is logical to presume that the similarity will extend to the maintenance of labor.

Accordingly, the logical manager, in repairing and maintaining labor and other resources, will not immediately repair any small damage, but will wait until the damage is significant enough to warrant repair or maintenance. This logical point lies before the point that they observe a decrease in the costs of repair/maintenance (at the maximum of the total cost of repair/maintenance curve, when the road begins to become not a poorly maintained paved road but a poorly maintained unpaved road). And the farmer certainly wants to act no earlier than when the rate of damage ceases to increase at an increasing rate (the midpoint of the average production [cost] curve): the farmer would be required to spend more resources to repair the labor than they would later when the rate

of damage slows. The farmer wants to maintain the damage at the point when the rate of damage begins to slow.

Ethical philosophies of labor management

There is an extension to this logicality, and that is in the case of living labor. The farmer is ethically obligated to care for their human, animal, plant, fungal, bacterial and viral labor *as much as possible*, even if it requires the farmer to expend more resources sooner than the farmer would otherwise. Yet do not say that the ethical farmer is less profitable: the ethical farmer increases productivity to compensate the inefficiency by gaining the honor required to motivate the labor into greater productivity.

Slaves work for little more than food, and can be compelled to work beyond the point of logicality, to the point of death. But free laborers will outcompete slaves: their liberty allows them to have a stake in improving their work. They are conscious of factors that might improve their labor and are motivated to undertake actions to increase the profitability of the company. A slave cares little for their own life, let alone the welfare of the company.

A slaveowner rewards only those slaves with high output or other total productivity; a manager of free men and women rewards quality. A slave is better replaced by a machine.

For machines, while the farmer usually relies on reasonable logic to ascertain the proper amount to compensate their labor (estimating the cost of maintenance by reason alone), the farmer may also do so mathematically. The behavior of all maintenance and production is predictable and follows the general mathematical function of $a+bx+cx^2$, where x is the amount of resources required for production or maintenance and a, b and c are constants that are related specifically to the individual production being examined. This "production function" is as useful as it is easy for the farmer to learn: by collecting limited data, the farmer may regress the entire curve the data is expected to fit. The farmer has no need to conduct trials to fully learn the dynamics of damage and maintenance.

Yet the farmer need not even resort to mathematical logic for living labor. Reason alone in this case is sufficient – and countless times easier for the farmer to undertake – than logic in determining the proper amount of maintenance to apply: the farmer already understands that no amount of damage may be tolerated.

So how does the farmer prevent damage from occurring to living labor?

Determining the rate of pay for laborers

For humans, all labor must not only share the burdens of the company equally, but must be compensated equally. Though the resource needs of every laborer is different, if the farmer compensates or provides the costs of living (housing, food, clothing and medicine), the costs of work (transportation, tools and specialized clothing and education), the costs of producing future labor (childcare and paid parental leave) and provides insurance against a future inability to work (both long term [pension] and short term [sickness]), the laborer's needs will likely be sufficiently met. Providing a small excess ensures that the needs are met.

The danger of rendering more resources to some classes of labor more than others is that the excess of resources is unwarranted. Why should the janitor earn more than the accountant? If the

labor has not fully earned it, the act of compensation will excite jealousy and slothful despair among the other laborers (animal and human). The wise farmer, to avoid this risk, simply compensates the entire body of laborers equally. This is wise not only for its low risk of danger, but also because it truly acknowledges that the efforts of all the laborers went into the success. The accountant could not have kept good records had their office not been cleaned, the janitor would never have gotten paid had the accountant not been keeping good records...and neither the accountant nor the janitor would have much to do had it not been for the harvesters! The circumstances when a laborer or a group of laborers is generally agreed to have done something extraordinary all on their own are very rare to the point of being nonexistent.

Some laborers will claim to the farmer that their work is especially difficult or odious and requires more pay. This is a false claim. No work is more difficult or odious than any other.

Compensation for training results in higher salaries for trained and specialized laborers or for dangerous work

Some work requires more training than other work because the work is more specialized. This reflects prior work undertaken by the laborer on behalf of the manager: they have undertaken to train and educate themselves, and should be rewarded for it.

Specialized labor is typically paid more than unspecialized labor when contracted by the farmer, but when the farmer employs specialized labor, the farmer is effectively paying the specialized labor no more than unspecialized labor per unit of work. The farmer is simply compensating the specialized labor for the costs of their education (apprenticing, schooling or other education is expensive). The same argument may be applied to those laborers who face greater risk of injury on the job: if they are compensated for the cost of insurance against the inability to work due to injury, the farmer has no need to pay them extra for their work.

The company that pays their labor for the costs of living, work, of producing future labor, and for insurance against the inability to work finds no reason to pay any laborer more than any other. No job, in of itself, is more important to the company than any other.

That said, any bonus given to workers should be given to all workers equally: their combined efforts of the present have little to do with their past victories. Rewarding only those with previous education and training does not encourage everyone to achieve future victories, but rather downheartedly wish they had the foresight to have already invested in their own education. It does not reward the work of everyone equally, and in the future, everyone will not be equally motivated to ensure that everyone is working equally hard. Why should the janitor clean the office of the accountant, if the accountant and not the janitor receives a bonus because the janitor keeps the office clean?

Bonuses should be equally distributed among shareholders; all laborers should be shareholders

If the farmer earns more than the costs of operation at the end of the year, the profits should be divided equally between shareholders. All laborers should be required to be shareholders in the company. Labor should be issued nontradable stock in the company eligible for dividends because by owning the company, the labor is encouraged to earn greater profit. Private companies should

still divide profits among the labor in the form of bonuses or gifts, being careful to distribute them equally among all laborers.

Laborers should be paid to cover expenses of luxury and opulence

Do not neglect luxury and opulence budgets for your laborers. Luxury, contrary to popular opinion, does not erode discipline. Discipline is the training undertaken by the managers. Luxury allows each laborer to develop their humanity, and strengthens their ability to work. Reduction of luxury erodes freedom, and the benefits of free workers enjoy over slaves.

Require work no more than one-third to half of every week

It is customary and good to allow each laborer 1/7 or even 2/7 of their week free of work, and 2/3 of their each day free from work: a total of about 69% - 71% of a week. This corresponds nicely with approximately two standard deviations of the hours: we are all creatures of rest. The root of this is in our physiology.[344] Bees take approximately the same time free from work, as do ants. In

[344] Eduardo Cesarman, MD and Norman Brachfeld, MD cowrote *A Redefinition of the Resting State of the Myocardial Cell* in 1976 in dedication *to rest, that neglected function.*

"This monograph is the result of our joint effort and expresses a theory designed to associate the laws of nature with those that govern the behavior of the heart. It is a different point of view in cardiology, one which we hope will stimulate research and discussion," wrote the authors.

Proclaiming at the beginning of their great work that "the darkness declares the glory of light" (a quote from TS Eliot) they bring into question whether the heart is at rest when discharging electrical impulses, or recieving them. "The myocardial cell alternates from a state of decreased entropy to one of increased entropy. The state of increased entropy corresponds to the mechanical contraction and that of decreaed entropy to the mechanical relaxation. Membrane potential 'activity' corresponds to a thermodynamic passive state (downhill) and membrane 'resting' potential to a thermodynamic active state (uphill)."

In other words, the heart is most active when building up energy between contractions!

"During the dyastole or 'resting' phase of the heart cycle, the myocardial cell reaches its minimal level of entropy, which means its greatest structural order, its highest level of information, differentiation and individuality. During this so-called 'resting' phase, the myocardial cell achieves its level of maximal potentiality to perform mechanical work, its point of maximal accumulation of free chemical energy. Also, while the phase of mechanica 'rest' continues, the myocardial cell reaches its furthest point from energetic equilibrium and is at its moment of maximual vulnerability."

But their book goes much further. "Perhaps resting and not having to be necessarily and compulsively usefull all the time could be good for human beings as well as the heart."

The authors describe free energy in the body as being similar to free energy in society, and both as being dangerous because they produce violence in their degradation.

Rest, they theorize, is an active state: when we rest, we, like our heart cells, are building up the energy to do greater things. When we do not rest, we use up what energy we had previously built up and our entropy is stabilized in a "rest" (dead) state. When we rest, our potential energy release increases and we are most alive.

the 29%-31% of the work week, it is good to give a quarter hour's rest to the laborer for every 4 hours of work, and a half-hour's break to eat a meal for every 8 hours of work.

Allow paid time off to the sick, the pregnant, newly married and other special-needs employees, include retirement benefits

The sick, the pregnant, the new-parent, the newly married and other laborers in need of more free time should be given it, so that their efficiency while on the job is greater. It was even customary in some ancient cultures to provide a year's paid vacation to a newly wedded laborer, and the afternoon snack and nap (siesta) was until very recently protected by law in some countries.

It is customary to pay a laborer 10% more than their needs, after retirement considerations are made, for luxury purposes. Customs change, but these guidelines are worthwhile for consideration, allowing a worker time to rest, time to improve themselves, time to develop their humanity, their loyalty, their joy in work.

Joy in work increases efficiency: too much work, like too many plants and too few aisles on a Tullian field, decreases efficiency

And joy in work allows for greater efficiency. Too much work decreases efficiency just as quickly as too many plants and too little aisles decreases production of a field. Too little pay is bad for business. Laborers who are paid a fraction of the total earnings of the company work harder to improve those earnings.

It may seem like wasted money and time, but it is not so. The wide aisles prescribed by Jethro Tull seem at first to be a waste of space, but they improve overall production and efficiency.

Security laborers and loyalty pay

Farming is the act of peace, and will always be under assault (if not actively protected by a government of law) by barbarians who earn their livelihood by war, theft and illegality.

It is sometimes necessary to defend the company's property against vandals, thieves or other criminals, against hostile government agents or soldiers. During times of danger (such as times of unrest, war or periods of greater criminal activity), all labor need not be equipped to respond to the crisis.

Yet a security force may be employed to defend the property and this specialized labor should be administered like any other. Bounties for trespassers encourage vigilance better than punishment for failure.

However, all labor must be able to assist the security force should the security forces prove to be insufficient for the crisis. These security forces will sometimes receive extra compensation not previously discussed: loyalty pay. When more security is required, more pay should be forthcoming to the laborers as they will be undertaking more duties. Besides which, loyalty pay preempts laziness and cowardice, and will (to some extent) reduce the risk of treachery or betrayal.

A careful balance between building up enough energy to live and not expending too much energy should be struck in everyone's lives.

Increasing employee ownership of the company also increases security: masters protect their property better than their servants.

Sometimes it is necessary to hire mercenaries. Mercenaries should be treated as any contract labor (which is to say, exactly as the farmer treats their own labor). In 2007, with copper and other metal prices high enough, thieves began to steal metal irrigation equipment from farmers in the United States. In response, some farmers (who had wisely already armed themselves and their labor) found it necessary to expand their defensive capacity by hiring an army of bounty hunters and security forces to hunt the thieves down. The mercenaries did not retain their ability to self-command, and instead obeyed the command of the farmers. In essence, the wise farmers treated the mercenaries as they would any other contracted labor: when a farmer hires contract labor to plow their fields, the plow obeys the command of the farmer because the farmer pays the laborer by the hour for the operation of the equipment. In this case, the army was paid a salary for the operation of the guns. This army was hired through the actions of the numerous growers associations that the farmers belonged to and paid dues to, but it is not impossible for unaffiliated farmers to raise an army without the aid of an organizational body.

In the most severe cases, the farmer will arm all their labor during regular work, but these severe cases are rare: armed laborers do not work so well as unarmed laborers for the reason that their energies are divided between two tasks, that of defense and that of their normal work. Weapons also get in the way of bodily movement and reduce productivity in other direct ways. Though it is an easy thing to say that the wartimes when labor must be armed at all times are times when the farmer should direct their labor towards the extermination of the threat to their farm, such wars can often take years to complete (far longer than the farmer could afford to wage them). Waging wars costs the farmer dearly, and the wise farmer finds any way towards peace rather than undertake the significant cost of battle. Yet the situation remains unavoidable in acts of colonization or in periods of civil unrest.

War should be undertaken swiftly if at all, but great luck is required if war is to be both quick and successful. The wise farmer does not rely on luck, but prepares themselves for a long, costly campaign. If the farmer is unable to undertake the costs of war, the wise farmer will abandon their farm and move their operations to a location with lower costs of security.

Outsourcing

Most farms will hire other companies to provide the services required, hiring security firms, contracting labor supply companies, hiring commission based field management (or, "sharecroppers"), even outsourcing marketing services. Few are the farms that don't hire a separate company to provide telecommunications services or electricity. However, sometimes it is worthwhile for a farm to undertake its own services and to oversee the service to the company a department manager is required, a person whose work is to manage the entire department.

Crisis management models require cooperation between managers and sharing of resources: a special manager should be appointed during the crisis to coordinate all resources

Any event that taxes the resources of a department to the point of threatening its ability to provide its necessary service to the company is a crisis and a crisis requires that resources from other departments be reallocated temporarily to relieve the pressure on the department in crisis.

During normal operations, the various department managers will work harmoniously together in a kind of oligarchy where coordination between departments is undertaken on equal footing. No department manager has authority over any other department manager, nor does the department manager require any such authority. The only requirement upon each department manager is the communication of information to the necessary parties: in example, the manager of customer service must inform the field manager what crops are required in what quantities and the field manager must inform the customer service manager when a crop fails or there is surplus that requires sold. To coordinate the communication between department managers sometimes a new department is formed (a communications department) or a manager for the department managers is hired. Because of the enormity of the task, it is wiser to form a new department to coordinate not only the communication between managers, but also to compile and analyze interdepartmental data.

However, during crisis operations, one or two department managers will necessarily be required to command their fellows and it is dangerous to have specialized each department's resources too much. This emergency could be everything from an armed attack on the farm (requiring the security department to have ultimate authority), to the neighbor's animals in the crops (requiring the authority of the field manager), to a large order being placed that exhausts supply (requiring the joint authority of the field and sales departments) or even the periodic (and expected) swarming of the hives (requiring the authority of the apiary manager).

In a crisis, the department managers must yield all available resources to the threatened department or else the entire company will fail. If resources have been specialized too greatly (human or animal labor trained only for one task, machines retrofitted to undertake only a single task, etc.), it robs the needy departments of available resources. It does the farm no good to continue plowing when vandals are taking target practice at the hives, it does the farm no good to continue selling products when the crops are being eaten by the neighbor's cattle...it does the farm less good to have only trained labor to undertake the tasks of plowing at the expense of defense, marketing or any other such service to the company. Every employee must be able to be useful to the entire company, and this means training themselves to be useful to any department that might require them.

Deciding how many resources to allocate from each department should be the job of a separate manager or department (the same which coordinates communication between departments) or else the farm runs the risk of conquering one crisis only to find another one in the throws of disaster: to run the cattle off the land does not necessarily require the entire customer service department, but may require one or two additional hands; to capture the vandals may not require the entire field management department, but will require a few more hands.

Less immediate crises, such as a department running over budget because (for example) of rising costs of production (such as the seed prices rising unexpectedly and forcing the field management department to run over budget) will require the infusion of monetary resources allocated to other departments. All resources are at the disposal of the department in crisis.

The farmer or communications department must resist the urge to place one department manager in charge during a crisis when two or more are required to have authority. Though commands are more easily generated by a centralized leadership, the expertise of the various department managers must be relied upon. It is very tempting for the farmer to place ultimate authority during crises in the communications department – who else knows the company better? But the specialized experience of the various department managers will better see the company through the crisis. It may even be necessary to recruit even more specialized leadership from the lesser ranks of labor: if many cattle are loose on the field and one of the laborers has extensive experience in dealing with cattle, the field manager (who is familiar with their labor and remembers the experience of that laborer) will temporarily promote the laborer to a position of authority (later, upon the successful resolution of the crisis, making a permanent promotion of the skilled laborer because they could teach others to train themselves in any number of obscure skills that might be useful to the company). The farm that is flexible in its leadership is one that can find the best person for the job at hand, whether it is a crisis situation or not.

The farm staffed by heroes – each one of them able and willing to undertake the most necessary services to the company – is a farm that will never fail, but will always adapt to changing circumstances and prosper against the worst the market and world can offer. Absolutely essential to this adaptability is the joint authority of labor and ownership to choose the management...and the loyalty of the labor and ownership to obey the commands of their chosen managers.

Emergencies are kinds of crises

It becomes necessary during martial and natural emergencies that labor follow the commands of their managers perfectly. The wise farmer will have their labor practice for every contingency, whether it is a worksite injury or an invasion of armed criminals or a fire in the barn or a flood in the fields. Labor must be as well disciplined on the field during planting as during battle.

Anticipation of emergencies is critical to response. Whether it is planning for the accidental dusting of the bee hives with pesticide or a tornado, if a well-thought plan is in place ahead of time, damage to resources can be reduced or prevented. Consultation with local emergency officials or with experienced elders will be critical in anticipating and planning for emergencies.

Train multiple employees for any particular job to guard against resource failure

Though a single individual may be better at a job than any other, should that individual be sick or injured or otherwise unable to undertake work, it is the company that suffers if someone else cannot be found to do the work. A basic knowledge of all positions in the company is required of all laborers.

The wise farmer trains their labor in all jobs so that the company is not reliant upon a single individual to make commanding decisions during a crisis, and is not reliant upon any individual who is so uniquely specialized that their services cannot be delivered by another laborer. The farmer will make sure that every laborer is able to focus on a single job at a time (even during a crisis) and is prepared for the various potential emergencies that may develop with complex and encompassing plans.

Disasters are those emergencies wherein a total or near-total loss of property or life occurs

Disasters are those emergencies wherein a total or near-total loss of property or life occurs. Natural disasters include earthquakes, fires, floods, excessively hot or cold weather, hurricanes or storms, landslides, mudflows, severe thunderstorms, severe wind, tornadoes, tsunamis, volcanoes and blizzards. Technological hazards include radioactive incidents, terrorist or anarchist attacks, hazardous materials incidents (and, especially on a farm, accidental over-exposure to dangerous chemicals by the foolishness of neighbors – Tullian farmers, of course, have no need for such things).

It is important to be aware of what disasters the farm is most likely to be at risk for, and be familiar with what kinds of hazards these disasters are associated with.

In any disaster, it is important that all people on the farm understand basic medical practices in responding to excessive bleeding, broken bones, and other common emergency trauma.

The objective is not long-term treatment, but stabilization in preparation for evacuation to a professional medical doctor.

While lessons are easily gained from medical professionals, and such classes are advised, some basic advice would include

For excessive bleeding: putting pressure over the wound with a clean cloth or absorbent material and maintaining pressure on the wound while wrapping it with a bandage, elevating the wound above the heart, and applying pressure to the veins and arteries that feed the wound to slow the flow of blood.

For shock: lay the victim on their back, elevate the feet above the heart by about 6-10 inches, maintain an open airway, control bleeding, maintain body temperature by blankets, etc., and avoid rough or unnecessary handling unless the victim and rescuer are in immediate danger.

For burns: cool the burned area and cover with a sterile cloth to reduce the risk of infection. If caused by a chemical, it may be necessary to CAREFULLY wash the wound. Do not use ice, as this will increase the injury.

For fractures and broken bones: do not push the bone back into the tissues, do not irrigate the wound. This is for professional medical doctors to do. Do cover the wound with a bandage, splint the fracture without disturbing the wound so that it is immobilized (even if that means splinting it at an abnormal angle), and keep the bone from drying out (if it is exposed to the air) with a clean, moist cloth.

Hypothermia: may be caused by exposure to cold air or water with inadequate food or clothing, and so wet clothing should be removed, the victim should be wrapped in a blanket or sleeping bag and their head and neck covered, they should be provided warm, sweet drinks and food, laid down and, if possible, given a supervised warm bath.

For severe wounds, amputation may be required. This is best left to professional medical personnel, but may be necessary in an extreme emergency when necessary to control bleeding and treat shock. The severed body part should be kept in a clean material, kept cool, if possible.

It is critical that injured persons and animals are prioritized based on immediate needs: there will likely be more victims than rescuers, limited resources and critical response times. Treat those victims with immediate (life threatening) injuries first, those that are in danger of death but not immediately so second, and those which are not in danger of death third. Any injured person able to help other injured people should be put to work in that capacity. Establish distinct areas for injured bodies to be placed so that those responsible for providing treatment can easily see which are requiring immediate attention. Bodies (alive or dead) should be placed with several feet between

each other so that workers can easily access each body. Even though injury might be obvious, conduct a head-to-toe assessment of each victim, looking at any injury, airway obstruction, excessive bleeding, signs of shock, bruising, swelling, severe pain, disfigurement to assess what treatement is needed. The most visible injury is not always the most serious injury to treat (such is the case for internal trauma).

Always document what is observed and what is done to facilitate medical professionals later. Always log the identification of each victim, their location and current medical state.

Similarly, damages to animals, buildings and other property should be considered based on immediate needs, logged and identified.

At the same time, any impending danger that could result in increased damage ought to be dealt with immediately. For example, if there is a fire that is approaching the chicken coops or pastures, animals ought to be released so they are not injured.

When collecting victims or managing dangers, begin where you are, and work your way outward. Be careful not to incur injury yourself: if you are fortunate enough to have survived with minimal or no injury, your fellow victims will require your healthy assistance. Take precautions against blood disease or physical trauma. If more than one rescuer is available, divide the work between those who can undertake work: some should treat victims, some should find and bring victims to treatment, some should find and prevent further damage, some should organize the evacuation and some should organize the temporary camp (becoming responsible for sanitation, organization, supplies, communications, etc.). Ideally, you have evacuated before the disaster, but this is not always feasible.

Always provide teams with writing equipment so that information can be logged. Develop a map of the farm and surrounding area of disaster so that those managers in charge of the situation can better understand what is going on and where.

Establish camps and medical treatment areas upwind and uphill of the disaster site to avoid contaminants, in a safe area that is free of hazards, and in a place accessible to roads to facilitate the transportation of supplies and possibly evacuation. It should have room for expansion, if the disaster is wide-spread.

Also see the notes on bandages in the chapter on working animals.

Specific disaster advice

It is, of course, best to consult with community emergency personnel before developing an disaster action plan, but some general advice for disaster management is basic and common sense. Thus, the most important advice is to very frequently stop everything, look, listen and think about what is happening, what needs to happen and plan how to do what needs done. Be methodical in everything from search to rescue to evacuation.

First hazards must be mitigated so that whatever disaster may occur is less likely to result in damages. Consider what would happen in the disaster, and attempt to prepare for it: if, for example, there is a risk of a fire in the hay barn, keep reservoirs of water or fire extinguishers nearby. In this line of thinking, it is good advice to require all people on the farm to know where circuit breakers, water shut-off valves, gas shut-off valves and other utility shut-offs are.

Also consider in advance evacuation routes and protocol from buildings and the farm at large. Horses and livestock that cannot be quickly loaded into truck or other transport should be freed so

that they may preserve their own lives – they can always be collected later. Also, have meeting places preassigned so that if people get separated during the evacuation, they can be easily reunited with their coworkers, family and friends. If there are a large number of people on the farm, have each manager undertake roll-call before evacuation (if possible) and at the meeting place, instituting buddy systems so that nobody is left behind on accident.

Assemble disaster supply kits of those tools and materials that will be required in the mitigation of or the recovery from the disaster. These kits should be easily carried away from the farm during evacuation or kept off-site at secure locations (such as the meeting place). Among these supplies should be food, water and basic medicine for people and animals, including those tools required to cook and serve the food and water, especially fuel. Depending on the disaster anticipated, several days to several months of food, water and medicine should be stockpiled, preparing for the duration between the disaster and when it may be reasonably expected that these basic needs may be met again. Spare clothes, blankets, shoes, hats, gloves, water collection tools, wild food harvesting tools and emergency shelters might also be considered. Perishable items should be regularly replaced in the stockpile.

Staple foods should be given preference, and among the medical supplies should be included multivitamins, laxatives (magnesium supplements are ideal for this), antidiarrheals, and your choice of pain reliever. Activated charcoal (for general poison control), potassium iodate (or kelp) for radioactivity, and other specialized disaster supplies should also be given consideration. On a farm especially it is important to stockpile those vitamins, minerals and medicines to anticipate accidental poisoning through the application of pesticide, herbicide and fertilizer – even though a Tullian farmer uses none of these, careless neighbors do.

Ensure that writing supplies are also in the stockpile for communicating directions during the disaster and recovery, and for keeping records (such as medical information, damages, histories, etc.). Whistles, lights, radios and other long-distance communication devices should also be considered.

Hygiene supplies should also be included, especially soap, water purification systems (even if it is only a large pot to boil quantities of water in), composting toilets, rags, etc. Biological wastes should be dealt with promptly.

Of course, supplies like matches, compasses, needles and thread, adhesives, basic mechanical tools (especially pliers), knives, edible plant identification books, etc. will help in the evacuation and recovery.

Important documents ought to be kept in the stockpile in duplicate, especially land deeds, birth certificates, marriage certificates, licenses, identifications, records, bank account numbers, and other documents that might be desired during or after the disaster. With these, include spare keys and maps of the area. These should be kept in a watertight box or canister.

Basically, stockpile anything you daily use, or would want during or after the disaster if the farm were inaccessible or destroyed.

After the disaster, psychological trauma should be immediately treated by medical doctors or spiritual councilors, or both. Failure to do so will result in long-term disability.

Final Commentary

The manager who serves their servants is served best by them.

CHAPTER TWENTY-THREE: OF WORK ANIMALS: BOVINES AND EQUINES

The foundational knowledge for training and keeping work animals applies also production animals and wild animals

The skills learned in training and keeping with training work animals applies also production animals and wild animals.

Veterinary care requires consultation with medical professional who has up-to-date knowledge

Because veterinary care improves daily at a rapid pace, we recommend consulting with a Veterinarian who is familiar with the most modern care, or with any of the excellent modern and up-to-date veterinarian science books in print.

Selecting a team

Training begins by selecting a team. While trained teams are sometimes available, often they are not and a team will be bought or born untrained.

Of the equines commonly used for farm work, heavy horses, light horses and mules are commonly employed, though donkeys have also been worked with success: mares are used more than geldings, and geldings more than stallions – though geldings and stallions make fine work animals. Of the bovines, castrated bulls are typically employed as oxen, though cows and bulls have been used with great success as well.

The castration of an animal changes his physical form. In cattle, he develops longer legs and a larger frame than a bull ever would (becoming taller and heavier), loses muscle mass in the neck and shoulders, reduces horn size and, with the near-absence of testosterone, the castrated bull is more complacent than a bull. Similar effects are seen with equines. However, it will be said again, that bulls do make acceptable oxen, and stallions do good work as well.

Both cattle species of the genus Bos are employed for work. The Bos indicus (the zebu, or humped breeds) is typically used in warmer climates and the Bos taurus is typically used in colder climates. Sometimes, the two species are crossed.

There was a third species of cattle (now extinct) used as oxen – the Bos primigenius (Aurochs, or Urus) which was similar to the Chianina – that was the first domesticated cow, but its wild nature and enormous size (it was bigger than any other cow currently in existence) made it unwieldy and the last of the Aurochs died in the early 17th Century in Eastern Europe.

Both equines and bovines are typically worked in pairs, with multiple pairs used for heavier work in transportation, logging and plowing very hard soils. However, it is possible to work both bovines and equines individually, as well.

While there are ideal standards for various breeds of equines and bovines and in selecting your pair you ought to consider well-bred animals, it is more important to match the animals within the pair based on their temperament, size and (if you are to ever sell the pair or show it at fairs) color. However, sometimes farmers will turn this rule on its head and we have seen pairs of intact bulls and castrated bulls, castrated bulls and cows, and even intact bulls and cows (though many farmers would consider this last combination crazy).

At any rate, the equine or bovine ought to be healthy and have relatively straight legs. Younger animals are preferred because they are more easily trained and have more working years ahead of them than older ones, and new-born animals are prized most as they will imprint upon their master if taken from their mother, becoming more obedient and ready to work than an animal raised by its mother could be. There is arguments for and against taking an animal from its mother, and one chief argument against it is if the mother is already trained by the farmer, the calf or foal will more quickly learn how to obey its master: both the farmer and the mother will be teaching it! Allowing the calf or the foal to "tag along" with mom (and maybe dad) while they work is an excellent way to prime them for their work life. Ultimately, it is a choice that belongs to the farmer whether the calf or foal is raised by its mother: if given the choice, the parent and the foal or calf would prefer natural parenting.

Since personality does not develop until later, many farmers will begin with 4 baby animals and pair them later when friendships naturally develop, selling the excess pair if they do not need two teams. Aggressive animals should be avoided, unless the farmer is looking for extra work on the field or desires a particularly beautiful animal for showing at fairs. Try to pair the animals by size, speed and strength.

There is no possible way to adequately discuss each breed, and with new breeds being conceived every year, it is best to offer general advice on selecting breeds. When choosing a breed of equine or bovine, you will be confronted with thousands of choices. Each breed has slightly different temperaments, environmental adaptations, colorations, sizes, speeds, and other differences that do matter. While the skilled farmer can make do with any breed, the smart farmer will take into consideration the differences in breeds and select one that is more suited for their farm. Typically, there will only be a few breeds nearby, and if you desire a different breed, you will need to import those animals.

If a child is to be doing the farm work, select a breed that is miniature: it is best to have several teams of small animals the child is able to master than to have one large team that is difficult for the child. Smaller breeds also are more efficient eaters and drinkers, and while the headache for many farmers is worth the extra feed and water of larger animals, it is worthwhile to consider small breeds even when children will not be undertaking the work.

Housing the animals

Equines and bovines are very hardy animals and require little or no shelter for comfort or survival in most parts of North America. However, in the arctic they will require heated shelter in the winter, and in the hot deserts, they will require a cool place to hide from the heat.

Yet many farmers will pamper their animals, believing that the more comfortable the animal is, the better they are able to work – and there is much logic in this. Besides, the kindness the farmer shows to their animals is responded to by the strong bonds and willing obedience of the animals. Unlike machines, animals are motivated to work by their emotional attachment to their masters and

are highly responsive to any pleasure or pain their master gives to them, responding even to the emotional state of their master (when their master is pleased, they are pleased; when their master is displeased or pained, they are displeased and pained).

In Colorado and in many places, shelter from hailstones, lightning and other weather hazards is appreciated by the animals.

Too often, the animals must be sheltered against thieves and vandals who would steal or damage their neighbor's animals. Vicious neighbors have been known to fire birdshot at horses and cattle to make them wild and unworkable and do worse in malice against their neighbor. Thus, these valuable animals are typically kept in the center of the farm near the master's house. It is also necessary to protect the animal against pesticide, herbicide and fertilizer applications that might poison them: when neighbors spray these chemicals, the chemicals will drift.

It is typical to use scarring to identify an animal: the animal is "branded" by the use of a hot or very cold iron so that their fur is removed or permanently discolored and the skin welts in a pattern that identifies their master. Less cruel and ugly methods are sometimes used, too: ears may be notched in a distinctive pattern, their colors and other identifying characteristics patented and recognized by the local government, or they are tattooed. We do not advise microchips or other invasive devices that are injected under the skin, as we have heard of cases where this has led to injury in work animals. It is best to physically mark an animal when it is young, as it will be less traumatized.

Animals are typically kept in stalls within the shelter or else offered a shelter with free choice and a small pasture to wander about in.

Ensure that the pasture is free of plants that might poison your animals. While the kinds of plants that are toxic vary considerably by region, consulting with neighbors or the local government will quickly educate you as to what plants should be removed from the pasture.

Each breed of horse or cow requires different amounts of space in the stall or in their pasture. However, a good guideline is to allow the animal (at very least) room to turn around with room to spare.

Ventilation is a basic need of hygiene, as gasses from their breathing and their digestion will poison the animals if not ventilated. Ventilation also helps regulate temperature in the building.

Bedding is necessary not only for the comfort and physical readiness of the animal (sleeping on a hard, frozen or muddy floor makes neither master nor animal ready for work, and can lead to damage to skin, feet, bones and muscles), but also for hygiene: bedding should be cleaned very regularly, and filth should not be tolerated to remain. Bedding should be absorbent to both liquid and gaseous wastes: straw or wood chips work admirably.

The flooring should facilitate waste management. While gravel, dirt, and sand drain best, they are impossible to clean. Concrete or stone is easy to clean but offers little drainage and less comfort. However, the hard floor can be matted with bedding and drainage pipes or other drainage systems may be installed to facilitate the drainage of liquid wastes.

Lighting is also a basic requirement of the animals. Natural light improves the temperament of the animals, and windows for the animals to view the outside world reduce boredom and also improve readiness for work. However, ensure that the windows do not allow much direct sunlight into the stall, as the animals may gradually blind themselves looking into the light. Either provide plants to block the sunlight from directly shining into the stall, tint the glass of the window, or raise the window above the height of the animal's head.

Food and water should be easily reached by the animal it is intended to feed and unreachable to other animals if the animal is kept in a stall.

If the animals are to be released into a pasture periodically, fences or walls ought to be constructed to prevent their wandering away. The animals will try to push the fence over, and it should be strong enough to withstand them. Wire, wood, stone and other materials make good barriers, and the custom of the farmer's neighborhood will typically dictate the best fencing for the environment.

Fences and walls are expensive, and a more affordable alternative is the quick-growing hedge. While different species are suited to different environments, the hedge should both be unpalatable to the animals and also able to withstand or repel them, either through dense hard foliage or wood, or through spines. They should also be ever-green. Junipers work well in most places, and besides the service of the hedge will provide medicinal berries: the berries, green, blue or purple (depending on ripeness) are antiseptic and, whether sucked to provide an antiseptic barrier in the mouth, applied in oil or undiluted as an ointment, or used in binds, can help both farmer and animal.

Their shelter and home pasture should be delightful to return to: if they ever escape, they should entertain the idea of returning on their own. Once a malicious neighbor opened the gates of a pasture so that the mules of a farmer would escape, but, having followed this advice, the mules contentedly remained where they were happiest, much to the consternation of the evil neighbor. But, even when there is little to fear from such evil, it is a wise idea in case of accidents which might destroy a fence or find a gate open when it should not be.

Feeding and watering should only be done when the animal is "home," and training should be undertaken to encourage the animal to return home on their own by freeing them first close to the open gate, and then gradually further away, rewarding them with a treat, praise and physical attention when they reenter their shelter or pasture. Training should also be undertaken to teach the animals to "go home!" Through such efforts, even if released in the middle of the field, even if the fence should utterly fail, even if the gate is left open, the animals will either remain at home or make their way back there to await their master.

Harness and yokes should be kept near to the stalls to reduce the effort required to begin working.

Diet

The diet of equines and bovines will be discussed in greater detail in the chapter on animal husbandry: work animals eat similarly to production animals, though some work animals may require more food than their productive counterparts, and some work animals may require less.

Special considerations for those animals not raised by their natural mothers must include directions for milk-feeding. Calves should be kept on milk for 6-8 weeks, foals should be kept on milk for about 3 months – though each individual may be different and a vet should be consulted before making any decision: naturally, some foals will nurse a year or more! Because bovines and equines are mammals, the feeding of milk even into maturity will not harm them, and will provide good (though expensive) nutrition.

During weaning, the foal or calf should have ready access to water at all times, and ought to be gradually introduced to adult foods such as grain, hay and pasture.

One approach to avoid milk diets is to allow the foal or calf to nurse with its mother.

It is understandable and expected that the working animal will be given a better diet than a production animal: they are worth more to the farmer. If special dietary consideration is to be made, consider supplementing the diet with minerals (the microorganisms in the stomachs of the bovine

and equine produce most vitamins not present in their food), and possibly a balanced protein supplement (though this is usually quite unnecessary). Usually, farmers will ensure that the feed and hay is absolutely without any spoilage, and will provide their animals with special treats (such as raisins, apples, oatmeal cookies, etc.) periodically.

For baby animals, consider feeding raw (unpasteurized) milk. Raw milk can either be purchased on the market, or provided by milking the mother. Raw milk has balanced vitamins and minerals for the growing baby who cannot yet rely on their native microorganisms to produce what they require.

Another special consideration for work animals is that they will likely be kept until they die of natural (old age) causes: the emotional bond between master and animal will (usually) prevent the farmer from slaughtering the animal at the end of its working life. These older animals may require more nutrient-dense foods and easier to chew foods: in other words, more treats.

Communication

Most animals develop a sophisticated understanding of human language and will understand not only commands, but much of what their master is saying – just as their masters gain an understanding into their animal's communication over time.

Using hand gestures to improve comprehension is advisable, but verbal commands are better than gestures. We had the opportunity to watch our neighbor's beef cattle one year: he had trained them to obey various commands of "come," "stay," "go home," etc. and he and his family were always chattering with the animals. However, the poor animals only understood the Spanish language of their masters, and while the hand gestures we were taught did much to convey our intentions, the animals would better respond to Spanish and gestures than English and gestures, and would respond better to Spanish alone than gestures alone.

Touch is an even better method of communication, and for both bovines and equines, during work touch commands are typically employed (as the noise of working sometimes prevents the farmer from effectively communicating their desires verbally).

Three methods of training: using social instincts of fighting, courtship or grooming to overcome other natural instincts

Training is a process by which normal behaviors are replaced with desired abnormal behaviors and thus training is easiest done when the animal is young and has not yet developed normal behaviors. However, in any case, the social instincts of fighting or courtship are used in training.

Fighting training is also known as harsh, get-it-done, or Yankee training. The master asserts dominance through demonstrating to the animal their physical helplessness and plays the role of a superior animal. Animals do not build animosity when fighting, they do not injure or abuse each other, but they do assert dominance through pushing and restraining bodies, and denying and granting resources. You may notice that superior animals will command inferior animals in their herd, and many of these same techniques are used by the fighting master. Included in the fighting response are some training methods that are traditionally understood to be courtship: when a new command is taught (such as "turn right") the animal is commanded and pushed in the direction it is supposed to go until it learns what "turn right" means.

Courtship training is also known as gentle, whispering, soft or compassionate training, and requires an intimate bonding with the animal: the master asserts their right to touch the animal wherever they please on their body, by requiring the animal to look to their master for resources, and by grooming the animal. The animal imprints upon their master as they would a friend or mate in their herd, and looks to the leadership of their master for guidance on how to behave.

Both methods work, both result in a positive relationship with the animal, and both result in the animal enjoying work (as much as any animal enjoys work). We recommend a combination of both methods and try to present that combination here. Both methods are most effective with young animals.

Natural communication behavior

Both horses and oxen must communicate with both members of their own species and those of other species, and while the science of their communication is still young, some progress has been made by professional ethnologists and animal behaviorologists into understanding both what these animals are "saying," and how to "say" things to them better.

However, most people who work with equines and bovines are familiar with the "language" of their animals – if only on an informal basis. Further, the animals quickly learn human language and while the ability of the human and their animal to make the noises which their communication partner is used to is quite limited (humans cannot neigh or bellow any better than equines and bovines could read this book), both human and animal eventually begin to freely communicate in their own languages, accepting that their partner will understand what is being said.

Dr. Sue McDonnell of the New Bolton Center at the University of Pennsylvania undertook the standardized collection of horse behavior and defining those behaviors, categorizing them into understandings of ritualized, unritualized, interactive, noninteractive, sequential and nonsequential behaviors. Though this, she organized her data into intermale interactions, harem formation and maintenance, breeding, parturition, parenting and early development, object play, play sexual behavior, locomotor play, play fighting, play initiation, domestically shaped and aberrant behaviors, and behaviors associated with pain and discomfort. If the farmer is unable to develop an intuitive learning of their animal's communication, they may at least develop a reasoned, logical understanding of their animal's communication through similar documentation.

Her ethnogram was "compiled with two general purposes. The first is to facilitate communication among people interested in horse behavior by organizing existing information and standardizing nomenclature in English. Whether one is a senior scientist, a graduate student starting a thesis project, a middle-schooler studying animal behavior or a horse enthusiast, it's useful to have an organized, accurate guide to the literature. The second purpose of this ethnogram is to serve as a field guide for anyone interested in observing horse behavior, whether formally as a trained biologist or informally as a horse owner or enthusiast."

As such, it also includes basic information on equine social structures. They are harem breeders that live in large herds made of many smaller bands. Each band consists of one harem, though sometimes there are more. Each harem consists of one mature breeding male (the harem stallion), a few mature breeding females (mares) and their young offspring. The harem stallion remains with their harem year-round, protecting them from comingling with other bands. The harem stallion is responsible for directing the movement of the family.

Thus, the farmer may imitate the harem stallion in directing the movements of their animals.

However, the stallion is only in charge of directing movements for defense and comingling activities, and one of the mares is typically in charge of directing movements to water, to a new grazing area or shifts within the day from grazing to resting. Thus, the farmer must also imitate the harem's lead mare.

A picture begins to evolve of the farmer at one point acting the part of a stallion, and at another point acting the part of a mare. And both stallions and mares have different leadership techniques.

A stable but rare variation of the single stallion harem is the two-stallion harem, wherein one stallion is an "assistant" and is permitted to mate with some of the mares in exchange for helping to keep the large harem together. This indicates that having two people work the horses, such as one leading and one driving, is viable so long as one is an "assistant" and whatever dominance activities are undertaken are undertaken by either the person leading or driving primarily.

Some bands do not have mares. These stallion bands stay close together and as close to the harem bands as the harem stallions will allow. Clearly, neither stallions nor mares are more easily banded. In the stallion bands, the stallions form partnership alliances of 2 to 3 animals.

Occasionally, mares will have no stallions in their bands. As they pass through the territories of various stallions, they (generally) submit to being mated. The territoriality of some equines demonstrates they are all capable of understanding territories, and location-based behavior. At the tack area, they understand they are to submit to tack. At the pasture, they understand they are free until called. On the field, they understand it is a place to work.

The equine band and herd has a social order, with some bands and individuals more dominant than others. But, with the sex-divided responsibilities, there is no primary stallion or primary mare for the entire herd or band. Indeed, there are several bands in charge at once. When several teams are kept together in a pasture, the bonded pairs will typically constitute miniature bands, and some of the bands will be more dominant. The master must encourage all the animals to bond into one band, and then present themselves as the band leader. If a herd situation develops, the master must assert themselves as master of each band, and will find some difficulty in mixing some of the bands together.

In the herd or band, some members will try to monopolize important resources, such as water troughs, feeding areas, shelters, favorite dust piles, etc. To overcome this, provide several water troughs well spaced apart so that one animal or band cannot keep others from it, provide feeding stations similarly spaced and provide large enough shelters to house each animal with some extra room to spare.

The farmer who would make one band out of their herd will work each animal with the others in rotation or randomly so that no two animals bond better than any other two. While this is not a perfect solution and sometimes several animals will be better friends with each other than with other members of their band or herd, it does reduce the herd instinct and increase the band instinct.

After the band stallion, the social order is not linear among the mares and young. A is not greater than B, and B is not greater than C. A may be subordinate to C but not to B, and C may be subordinate to B but not A. And A, B and C may each have their own relationship to D. Typically, once established, the order remains stable until significant changes to the environment occur. This tells the master to make an individual relationship with each animal, and not to rely on a band stallion or head mare as they would a head rooster or head hen: while a head rooster or head hen can be trained to round up their flock and bring them to the coop or to the master, the training simply cannot occur with equines or bovines. Equines and bovines, in this sense, are more similar to geese,

which, while having a head goose and a head gander, must come to consensus before undertaking something as a flock – or else each be compelled through their individual relationship with their master to do what is required of them.

Thus, training to presentations of resources is the farmer's best option: by shaking a grain bucket, each individual animal will understand the promise of a treat, and will come out of the pasture to work. Those which do not feel like working will follow those that do to stay near their herd. In this case, the farmer needs only to convince the majority of the dominant animals to come and they will all come. However, in work, the farmer must convince each individual animal to work – using the social instincts of fighting, courtship and grooming.

Within and between bands of horses, very subtle changes in ear or tail positions convey information. Head tosses and threat gazes are often enough to change the direction of a band of horses. Horses emit a variety of vocalizations as well as other sounds that serve as communication, too (including whinnies, neighs, snorts, squeals and grunts). More subtle vocalizations, such as the groan and sigh, are intended for one-to-one communication. Hoof sounds, from pawing, stamping or contact with the ground during running or walking, also convey information. Chemical emissions also communicate messages, including chemicals on the breath, in the urine, in the feces and possibly through the skin.

Grooming is important to play and socialization, especially in fighting. It is important to begin work with grooming so the animal understands if it gets hurt, there are no hard feelings and the whole event is play.

Horses interact successfully with other species, playing often with ground squirrels and foxes, and many bird species have learned how to herd horses away from their ground nests. Horses will also transport birds that choose to ride on their backs. No doubt, these successes of the birds inspired the first people to consider taming the horses for transportation and work and studying their behavior for inspiration on how to undertake training.

Training

Equines and bovines are simple in their normal behavior. They need food, water, rest, shelter and some social interaction. However, they are not highly responsive to kindness and attention from humans, as humans are not their own species. Most animals do not enjoy work, and expecting them to work for hours on end requires radical changes to their behavior: working takes away from their normal behaviors of eating, drinking, resting, sheltering and socializing.

This radical change is very stressful to the animal, and it is important to allow frequent rests during the earliest phases of training.

Bovines and equines are gregarious, social animals. They seek the companionship of animals of the same species and develop strong bonds within their herd. The bonds are so strong that when an individual is removed from their herd, they are seriously distressed (this is another argument against purchasing animals already grown and bonded to the people of another farm).

However, they bond only after they have learned whether they are dominant or subordinate to another member of the herd. When worked in pairs, the presence of another member of their species has a calming effect. Using a well trained animal within the herd to train a new animal is a good idea, so long as the well trained animal is dominant to the new animal.

A pair of animals used to working with each other will suffer significant stress if separated and will, in their free time in the pasture, even remain side-by-side as if in the yoke or harness. This

is one argument to changing up the composition of your teams regularly: if you don't and one member of the pair dies, the other will be too distraught and unused to working with other animals that they will be useless.

Animals establish their dominance by force and fighting, and thus establishing a dominant relationship with a younger animal is easier than with an older animal. However, subordinate animals are regularly testing their dominant counterparts (and their masters) through play. It is not necessary to harm the animals, and since equines and bovines are, so to speak, easily cowed, establishing dominance is not difficult. Yet establishing dominance with a mature animal not used to work can be dangerous.

Some breeds are more gentle and easily trained than others, but their unique personality must suit their master's and it is impossible to provide even general guidelines on the various breeds.

Being fair, kind and gentle will help the training process, but it will not train the animals. It is important to not discourage the animal during training: a tired animal still pays attention, but an exhausted animal learns little.

Training of young or new animals is an excellent job to be given young family members: as they train their animals and grow up themselves, their animals will be ready to work when they are grown up enough to work their animals. Also, the children will have enough time to dedicate to the better training of the animals, and better trained animals will be more productive.

The best teachers of new or young animals are older or more trained animals. Hitching even several young animals next to a more experienced animal will allow the younger animals to look to their natural teacher for guidance on how to react to various commands. Sometimes, a single older animals is hitched next to even four younger animals!

Remember, keep your lessons simple: the more that a skill is broken down into its component behaviors, the quicker and easier the animal will learn and retain the skills you wish them to learn. Work the animal or play with them a little before the lesson to reduce nervous energy, and in case the animal gets frustrated or confused and scared, make sure that during the lesson you remain safely out of kicking range – in a moment of nervousness, the animal might do something they don't intend to. That said, training is usually very safe – but it is wise to take precautions against every emergency.

Avoid tying foals and calves as it may injure the young animal, and also teach them bad lessons: they'll think you are always so big that you can restrain them and forcibly move them and when they grow older and they are bigger than you, when they learn that you are now smaller than they are, they will lose much motivation to work. Use constant, concise cues for your animals: complicated directions are difficult for the animals to obey. Try to limit training sessions to less than 30 minutes at a time: training is hard work for the animal!

When training animals, no matter how experienced they are, move slowly about them: they are highly strained and you don't want to add to their nervousness. Quick, sudden movements are not good for training.

Remember that you're the boss. If your animal turns and runs away from you in the small pen, do not chase them. This will cause them to fear your approach. Command them to stop and turn to face you, or force them to confront you by remaining in the middle of the small pen. Eventually, they will relax and recognize you are not a threat. When the animal is relaxed, begin the lesson again.

And give very frequent rewards. Whenever the animal responds correctly to the commands or improves their response, immediately reward the animal with rubs, encouraging words, and a moment of relaxation. This conditioned response technique will gradually build their response and skills. Edible treats don't hurt, either.

And always end the lesson with the animal relaxed and confident: this will build their confidence and keep them wanting to learn more.

Establishing dominance

One way to establish dominance and retain it is to constantly capture and restrain the animal. This is done best not through body force (even a foal or calf is difficult for an adult human to restrain), but through ropes and small pens. Making it a game that is enjoyable for the animal, associating getting caught and being subordinate with rewards is the best way to go.

Another good way to establish dominance is through the constant provision of needs: the animal does appreciate your attention, and associates with you as a calf or foal would to their mother. Treating injuries, providing treats, freedom and other kindnesses and other good deeds pay back manifold.

Never train with negative reinforcement: while you may be able to intimidate the baby animal with whipping, hitting or other force, when the animal one day discovers that it is bigger than you are, and that your whip, stick or other weapon does not actually harm it much, it will be the animal's turn to teach you a lesson through negative reinforcement and you will get severely injured. It is much better that your animal loves you than fears you.

When using force to demonstrate dominance, some masters will restrain the animal and even sit on it until the animal stops resisting. The horse, in this way, is presented with its worst nightmare and is forced to confront the reality that its master will not hurt it, even when it is within the power of the master to do so. In combination with positive and negative reinforcement, the restraint method works better. It is, essentially, an intensive provision of needs: the animal is made to need security, comfort, food, shelter, etc. and then given what it needs. But the restraint method never works so well as gentler methods.

First lesson: overcoming flight response

Of course, if the animal is used to you from a young age and imprinted on you, you won't need to overcome their flight response.

However, for older animals, the first lesson that must be taught is to overcome the instinct to flee the approach of their master. As prey animals, both equines and bovines naturally flee when approached. However, if the animal is to work with a human, they must overcome their flight response and evens seek the attentions of their master. They also will naturally have a fear of the unknown. However, during farm work, new tasks and situations naturally evolve and it is necessary that the animal not be easily frightened by their novelty.

Flight, in all its manifestations, is overcome by a simple training exercise repeated often and throughout the animal's life, the objective of which is desensitization: flight cannot be untrained, it is too much the nature of the animal. However, the threshold at which the animal is inclined to run can be raised, and it can be made to be accustomed to novelty and its master, understanding through consciousness that these things are not terrifying.

Trying new things, learning new tasks or tricks, exploring new areas or encountering potentially terrifying things (such as ropes on the ground, clanging chains, highway traffic, etc.) improves the animal's confidence when forced into a new situation and builds their trust in their master's commands during the episode.

Handling the animal every day in a loving way, approaching them with food (so they associate you with good things), and otherwise building trust is a good approach for baby animals, but for older animals, more complex training is required.

When you approach an untrained animal, its head will be directed toward you and it will orient its eyes, nose, ears and entire body to observe what you are doing. As you continue to approach, it will develop a state of alarm or fear. Approach a few feet more and the animal will turn and run.

If the animal is in a very small (15-30 foot diameter) pen, the animal's flight will be checked by the walls or fence of the pen.

Enter the pen with the animal and do not approach the animal. If you stand in the middle, the animal will quickly realize that there is no "furthest" or "safest" spot from you. Wait until the animal turns to look at you, then turn to face the animal. When the animal's fear response is diminished (you can tell by the ears, breathing, and posture of neck, especially – these are the most communicative aspects of bovines and equines), end the lesson. At the next lesson, repeat the previous lesson, and if possible (if the animal is relaxed) begin approaching the animal. When you can touch the animal, end the lesson. At the next lesson, introduce the halter to the animal by touching it to the animal's body all over, and then, gradually, introducing it to the animal's face. When you can put the halter on, end the lesson. At the next lesson, attach the lead rope to the halter. Eventually, the entire harness or yoke is introduced this way.

Sometimes, though, the animal is so crazed from previous owners that they are entirely unresponsive to gentle training, and the master must treat them as disobedient animals: instead of overcoming a flight response, the master must overcome an animal that likes to run away. See the section in this chapter on typical training problems with difficult animals.

Second lesson: overcoming fight response

Aggressive animals are no fun to work with and when, occasionally, aggressive animals attempt to intimidate you, you must demonstrate no fear and not let their bad behavior go unchecked. Never retreat or cease your demands: though the animal is many times your size, you are unlikely to get hurt unless it thinks it can dominate you. That said, use caution and common sense as you reinstitute basic obedience training.

It is not necessary to physically harm the animal, but it is necessary for them to observe that, despite your size, you could fold them up and put them on a bookshelf if you wanted to. Some old cowboys we know would take their hat off to an aggressive animal and bonk their noses with it. This is inspired by the natural fighting methods of the animals, wherein two animals will intimidate and wrestle without causing actual harm to each other. While not causing harm, this method demonstrates a reserved strength to the animal and the animal quieted down, respectful of their master for not harming them. But it is not good to be wrestling with your animals – it takes up time, it is potentially dangerous when they are harnessed or yoked, and it is above all else an inconvenience.

We have also seen (and advise) another method of quieting animals. In this whispering method, the aggressive animal is treated with kindness – not as a reward, but as a sign of strength. The animal's nose is not bonked, but stroked; the head and neck are touched as well: the master reasserts their authority by claiming their right to touch the animal wherever they please – and all over the animal, in fact. This is inspired not by the fighting methods of the animals, but by their

courtship rituals, wherein the pair assert mutual dominance by claiming the right to touch. Such touch is not rewarding, but is aggressive in nature (even if it is kind and gentle) and is thus ideally appropriate for the aggressive animal who has bonded with their master. In this vein, in nature occasionally one or both of the animals will nip each other, and in severe cases of disobedience or aggression, a combination of both bonking and whispering is required.

The key is to use the animal's natural behaviors to communicate with it. Just as they learn your language to do your work, you must learn their language when they have social needs. Aggression is, usually, demonstrating a need for socialization: and much of the social life of these animals is spent learning who is boss through aggressive (but usually loving) behavior.

We have also seen mixed success through hypnotism. We saw an infirm elderly woman sing a droning song to a raging semi-wild escaped bull from a distance, slowly rotating a stick 180 degrees in a repetitious movement. The bull, captivated by the song, was soon captivated by the rope in her other hand, tied securely around his horns. Not everyone can do this trick, but when it works it is most impressive.

Never try to physically harm an animal. It untrains their trust in humans and their master, and makes them less likely to be obedient in the future, and more likely to be aggressive. It is not loving, nor social. An old vaquero (a Spanish term for cowboy popular among the Mexican immigrants of Colorado and elsewhere) would twist tails, throw stones at, whip, hit, punch and otherwise harmed his animals when they were disobedient or aggressive. This generally made them less well behaved, even if they were cowed into more submissive behavior. The more he used these techniques, the more they were required. One day, the old vaquero was thrown from his aggressive horse while he was spurring it into submission right into the midst of his cattle whom he had previously attacked into submission. This sudden intrusion into the herd, combined with the apparent subordination of the vaquero to his horse, led several of his cattle to think they might challenge him and an incident he later recalled as being "almost funny" resulted wherein he was chased about his ranch by his cattle and horse until his ranch hands rescued him.

Some will say that stallions and bulls are more aggressive than mares, geldings, cows or steers. However, this is untrue, and anyone who has had the pleasure of owning many animals will agree that some of the most aggressive, stubborn and angry animals are not intact males.

A grooming method of training

A more obscure method of training makes use of the social instinct of grooming. The animal is regularly touched, cleaned and rubbed by their master. Ropes, harness, yokes, tools of all kinds are used to rub the animal so that the animal begins to associate them with grooming: in this way, the animal learns that work is pleasurable. When the animal is tied up in the harness and hitched to a plow, the master rubs them and praises them, and the constant positive reinforcement gradually encourages the animal to want to work. The animal is introduced to many "scary" new things they may encounter on the road (snakes, horns, etc.), but in a way that the animal learns that every new thing potentially will rub it and praise it and be cause for a treat. It is very similar to how dogs are trained: many, many treats, much, much positive reinforcement: even if the animal gets entangled in their ropes or straps, even if someone comes running up to the animal out from behind a building with a loud drum, no matter what happens, the animal expects the world to love it.

Needless to say, this training requires constant positive reinforcement whenever a task is done well as the animal will perceive the lack of positive reinforcement as punishment.

However, we have found that with some animals, their temperament does not allow for the success of the grooming method, and they do require fighting and courtship rituals as well.

Controlling sensory awareness

Sight allows both bovine and equine nearly panoramic views of their world. This is good, as it can allow the animal to perceive their master and their master's commands. However, when combined with the inclination towards flight, it can be quite detrimental to work. So, many farmers will blind their animals with cloth or leather during work so that the animal can only see in front of them and below at their feet (without this, the animal may misstep and harm themselves or their master, or not undertake the work well).

These animals also both have good hearing, but are easily distracted and if they are focusing on the sound of their work, they can pay no heed to the commands of their master even if they want to. The animals love the sound of their working: it is pleasurable, and they are pleased they are doing such a good job. In this state of distraction, yelling at the animals does no good: though they can hear you over the din of the machines easily, they are not listening to you.

Still, it helps to train them to voice commands because they do shift their attention from time to time and do try to listen to their master first. Associate each verbal command with a corresponding tactile command to improve communication. Yet verbal commands required of equines and bovines must be easily differentiated on their own. Sometimes, farmers will add syllables to improve differentiation, but often the sound of the words is different enough.

While the farmer will undoubtedly have commands specific to their operation, typical commands include:

1. Move forward, forward, get up, get ye up, go
2. Slow down, slow, easy, easy there
3. Stop, whoa
4. Turn right, right, gee
5. Turn left, left, haw
6. Step towards the pole/chain, step in, in
7. Step away from the pole/chain, step out, out
8. Move backward, back, back up
9. Stay, stand, don't move, stay put (sometimes followed by expletive)
10. Head up
11. Come to master, come to boss, come boss (which is also farmer humor, suggesting that the animal is boss)
12. Go home, go to pasture, go to barn
13. Their name – so that commands can be given to an individual animal (ex. George, come!)
14. "Team" or their species – so that commands can be given to multiple animals (ex. Oxen, go! or, Team, go!)
15. Foot up, lift foot, foot (so the veterinarian, groom or farmer can attend the feet)
16. Steady, calm down (especially useful when an inexperienced veterinarian provides a painful vaccination or inspection)
17. Load yourself into the truck (or other animal transport, if the animals must be transported)

18. Sidestep right or left (just one step to the right or the left), right step, left step, budge, move over
19. Lay down
20. Stop, behave (warning of disciplinary action in cases of aggression)
21. Good, good job (or other verbal praise or positive reinforcement)
22. Bad, bad job (or other verbal negative reinforcement)

We have also seen a well trained horse that was taught to "feed itself" and help itself to a specific quantity of food. However, this horse seemed to be unique, and as most people have not even mastered this skill, we wouldn't trust most animals to feed themselves without over indulging.

It is important not to chatter to the animals while they work so they can more easily hear when you are providing commands. Also, prepare them to hear a command by calling their name or their team or species. Some farmers find better success in training animals to hear a command with a click or a whistle: the whistle will be blown, and the command issued. This is useful if the animals have a hard time learning their own name (which some animals learn better than others). Be very consistent in your commands so the animals have no reason to be confused as to what you want and do not provide a new command until they have obeyed the last one.

Both cattle and horses have extraordinarily sensitive skin, able to feel a fly walking upon it. Thus, when providing physical commands, it is not necessary to touch the animal vigorously. The whip or goad should have a soft cloth or string on the end of a stick so that in usual cases, the soft string is used for commands and the stick is reserved for disobedience or when extra clarity is required during distracting situations. Never beat the animals with the whip or the goad: work should be a pleasure, and they should not fear the whip or goad. For that matter, never beat the animals anyway: they will learn to fear you and the careful efforts you undertook for bonding with them will be eroded.

Never make capture or work painful to the animal and they will eagerly look forward to it: work, because it helps them overcome their natural fright and aggression, is naturally pleasant, and the animals are pleased to obey a master that takes an interest in their improvement.

Understand that the animal is highly intelligent, and treat them as you would a child human. Like children, they learn best with a loving teacher. Songs and other joys captivate their attention, and speed the learning process. In our experience, equines prefer heavily rhythmic music, and cattle prefer more airy tunes.

Like children, the animals learn best from those masters they have bonded with. Be patient with them, they are doing their best to learn, but do learn slowly. When they do not learn, blame yourself – not the animals. You are in control, they are not.

Like children, the animals learn well with habituation. Habituating an animal to heavier and heavier loads and work also speeds the learning process: asking an animal to pull a large weight without working up to it causes the animal to doubt whether they can pull it. Begin training by requiring only 10% of the animal's body weight be pulled and you won't be starting off too hard (a trained animal can pull sometimes more than their own body weight if habituated to doing so). The physical conditioning required to pull great weights requires regular exercise and strength-building work: the mental preparation required to undertake the difficult work also requires regular efforts by the trainer master. Just as good oxen are kept in shape through regular work (even when there is little work for them to do – a rarity on a farm), their mental habituation to difficult or new work

should also be kept up. In this vein, it is important to sometimes switch which side of the yoke an animal is placed.

The animals learn by imitation of already trained animals and eagerly look to the lessons of their elder animals for guidance toward their own behavior. Let older animals train younger ones.

They learn, too, to obey commands and learn what each command means through association. Reinforce through positive and negative responses as the animal learns what is required when "go" or "stop" or "lay down" is commanded through voice and touch.

In no case should you let the animal quit work without your permission or without completing the job asked of them, otherwise they will gain bad habits. Do not let them go back to the pasture until you tell them to "go home." Sending them straight back to pasture after unyoking or unharnessing them is setting yourself up for disobedience. Do not have an established routine for quitting work and they will obey you until you allow them their freedom. Even vary the route back to the pasture, the time of day and the area in which they are tethered before being unharnessed or unyoked. Have an established routine for starting work associated with feeding and they will be ready for work each day at the right time.

Choosing names for the animals

When naming your animals, choose easy one-syllable words that do not sound like any other name on the farm, or any of the commands. Naming a pair of animals Maw and Paw is a disaster: they sound alike, and also like the command "haw." The name must have meaning for the farmer, as well, if the bonding process is to work very well: farmers might find success with numbering their animals (naming them, "one," "two," "three," "four," etc.), but this does not aid the bonding process between farmer and animal as numbers are impersonal.

Third lesson: work

Working begins first by teaching the animals how to follow their master and to submit to grooming. The farmer will tie a rope to a halter and lead the animal around, and before and after leading groom the animal.

When at last the animal is able to be led, they are introduced to the harness or yoke and continue with leading practice: they learn by this how to follow their master in the field while wearing the harness or yoke.

As the farmer is teaching them how to follow, the animals should also learn how to start, stop, turn right and left, and other commands necessary to work. Introduce these commands gradually!

Eventually, the animals are ready to pull a load attached to their harness or their yoke. Begin with very little weight to accustom them to the idea that they will be pulling something behind them (this can be very frightening to an animal). Then, gradually increase the weight, continuing with training in various commands.

Gradually, stop leading the animals and command them from behind as you would during real work. And, when this is no longer a problem, introduce challenges such as obstacles, only verbal or only tactile commands, or small frightening things, etc. Vary the training so the animals never know what to expect and they will be more and more obedient.

When, at last they are ready to work in the field, it will seem just like another day of training!

Always end training on a positive success, not after a failure. Reinforce to the animals that their freedom and reward for a hard day's work is contingent on their good behavior. They may lay down, or become aggressive, or try to force an early end to the workday, but you can't let them have their way. They must work before they are released.

If you are going to be using harness, train the animals from a young age how to respond to the reins. The way this is done is to attach the harness and the reins and then "ground drive" the animals without them pulling anything and their master walking behind them. Eventually, have the animals pull a light weight or a platform or sled for their master to stand on. Some farmers will instead use a light cart instead of a sled, but it makes little difference except that a sled is easier to dismount in an emergency during training.

One form of useful training is the whipple tree. Normally, the whipple tree is used to generate power through the turning of a gear as the animal pulls a shaft attached to the gear. By this way, grains are ground, water is pumped, tree stumps are pulled from the ground, etc. When the whipple tree is not attached to a gear, the animal is forced to face one direction by the way they are harnessed to it, and thus learns directions somewhat easier. However useful whipple trees are for power, they are inferior to other training methods that allow the animal free choice on what direction in the pen to face: the animal will not always be tethered to a whipple tree and it is useful to teach the animal how to behave so that, even in an open pasture without any harness or yoke, they will want to and be able to follow directions.

How to use a whip or goad

Though the farmer may opt to train their animals in different ways, common methods of communicating commands by whips or goads are based on the idea that the whip or goad pushes the animal in the direction required.

1. Go forward: several taps on the rear of the animal
2. Stop going forward: Placing the whip or goad in front of the animal's head, nose or chest without a tap
3. Go backward: several taps on the animal's head, nose or chest
4. Stop going backward: Placing the whip or goad behind the animal's rear
5. Turn left: several taps on the right side of the animal
6. Turn right: several taps on the left side of the animal

And so on. When the animals are paired, it is sometimes necessary to give individual directions to each animal (for tight turns, one animal may need to go forward while the other goes backward or stops).

How to use a bit

Bits are devices which attach to reigns and allow the master more easily communicate with the reins to the animal. As with using a goad or whip, only the lightest and gentlest pressure need be used to communicate: the animal will certainly feel whatever signal you send to it. Many people pull

too hard on the bits, and this not only desensitizes the animal to the signals, requiring harder and harder tugs, but also irritates the animals and reduces work efficiency. It is best, while learning how to use a bit, to use less pressure first and then more pressure. Barely tug on the reins and issue your command verbally. Increase pressure until a response is obtained. Do not get used to that pressure, as your animal will likely become sensitized to your subtlety and will require less and less pressure as time passes: begin each training and work session anew, with very little pressure.

Needless to say, if many animals are used at once, hold all the reins that correspond with the right side of their mouths in the right hand, and all the reins that correspond with the left side of their mouths in the left hand, and do not let the lines cross.

Good training practices

In undertaking physical training, always start with a light load and gradually increase the weight the animals are bearing.

Train daily or twice daily with short workouts with no regular farm work and work up to less frequent long workouts in between regular farm work.

Bovines and equines less than 2 years old are not fit for regular work, and standards should be lower for them.

Constantly monitor the fit of the yoke or the harness: if they do not fit, the animals will not pull well and risk injury. Also ensure that the forecart or pull chain is appropriate to the weight or equipment being pulled.

Ensure that both animals are pulling together by practicing starting and stopping.

NEVER: overload a young or inexperienced team, overwork a team to the point of injury, overuse the whip or goad to encourage a young or inexperienced team, pull long distances without frequent rests, use misfit yokes or harness, turn corners so tightly that the draw chain is caught under foot, work a young or inexperienced team on mud or ice or in deep snow, or work a team when you yourself are in a foul temper (it will lead to you making mistakes and causing the experience to be an unhappy one for everyone involved).

Typical training problems with difficult animals

However easy training is, training may not go well, especially if undertaken by an amateur with a difficult animal. However, some of the more common difficulties are easily managed.

Teams that like to run away and ignore the command to stop have learned to overrun their master. The danger and hazard of such a team is obvious. Likely, the animals have learned that if they run away, they can avoid work. Training in a small pen with stop and start exercises will aid in correcting this as the farmer can count on the pen walls stopping the animals and aiding in turning the team back to the farmer if they do start to get going (approaching the barrier, the animals will turn right or left and, if the pen is very small, find themselves face to face with the farmer who will better be able to convince them to stop). Tell the animals to go, and keep chasing them: they will find themselves obeying you. Then, tell the animals to stop, blocking their ability to keep going. Lots of praise and lots of fun will show the animals again that working is enjoyable.

Another reason why teams run away is that they have been previously beaten. This happens too often, and the team that is afraid of people will not want to work. Trust building exercises, especially the start-stop exercise previously described, and touching the animal all over to reassert

gentle dominance will help. The animals will appreciate any kindness you offer them, and the gentleness of your approach. Make working with you enjoyable, and they will enjoy working with you. Cause you to be dominant in the working process and they will be obedient to you.

One of the best ways to train an animal to "stop" is with the "Running W." Two bands above the front hooves are attached, and a ring is attached to each band. A band is attached around the belly of the horse, and three rings are attached: one on either side, and one in the middle behind and in the middle of the two front legs. A rope is attached to one side of the horse, run to the nearest hoof, then to the middle of the belly, then to the other hoof, then to the other side of the horse and the end is held by the master: on the horse, the rope makes a "W" shape.

A person of moderate strength can, by the Running W, trip or slow down or drop an animal. Typically, the animal is told to go (or is already going). They are then told to stop. If they do not stop, the command is repeated louder. If they do not stop, the command is repeated as the rope is pulled and the horse is slowed or dropped. It is best to do this on a soft ground to reduce the risk of injury to the animal. The animal quickly learns what "stop" means. Be very sure to provide excessive positive reinforcement as well: if the animal stops, give it many treats and praises.

Some masters will drop the horse and keep the horse on its knees until it stops resisting to reinforce the master's dominance over the animal. By demonstrating the horse's utter helplessness, the horse looks to the master for direction.

Animals may also jump chain, or get on the wrong side of their chains. While this may be due to errors of the farmer in fitting and setting up the chains, yokes, harness, and other equipment, it may also be due to confusion of the animals, or the animals having learned that if they do so, they gain a rest from work. In any case, intensive training is required to demonstrate to the animals what is expected of them, that work is enjoyable, and to refresh the farmer in proper equipment set-up. If the problem persists, try using drive shafts instead of chains, and/or hitching to a forecart to keep the chains or post high enough off the ground that the animals cannot jump chain.

A forecart is a small cart that weighs little, but to which implements can be attached in the rear, and drive shafts or chains can be attached to in the front high off the ground. Models designed for a single animal will typically attach to the animal's collar or yoke on either side of the animal, whereas those designed for a team will have a shaft down the middle that attaches to either a bar that hangs between the collars, or to the center of the yoke itself



Right: a forecart designed for a single animal attaches on either side of its collar or yoke. Bottom: a forecart designed for a team will typically have a shaft to attach to a bar or to the yoke; the right image shows how an implement attaches to the forecart.





An alternative to forecarts are sleds.

Both sleds and forecarts are easily made at home. A sled is nothing more than a platform (typically 4 foot by 8 foot) atop two 10 to 12 inch wide runners. Sometimes, depending on the load, wider runners are used. Sometimes the runners are waxed on the bottom to decrease friction, sometimes they have a slippery surface (such as leather, plastic, etc.) affixed to the bottom to decrease friction. Once we have seen a sled with small ball bearings on the bottom, and this worked tolerably well on hard surfaces where the mud would not clog them.

Having the runners be a few feet longer than the platform allows for a beam to be inserted between them and a shaft attached to a swiveling tongue attached to the bar. Of course, the platform ought to be reinforced with beams if the sled is to be used to carry things. Sometimes the platform is enclosed with walls to improve its ability to hold things. To the farmer is left the discretion of many aspects of design. The forecart is easily made by inserting axels to the runners and putting wheels on the axels. A chair or bench is also typically provided on a forecart.

Some forecarts are very small, only 2-4 feet long, and will have only two wheels. Some are of intermediate length, and will have three wheels. Again, depending on its use, the terrain and the farmer's inclinations, there is much flexibility in designing a forecart.

Attaching a hitch to the rear of the forecart or sled allows other implements to be pulled.

Another option for curing chain jumping is to let the animals stay on the wrong side of the chain. It is so uncomfortable that the animals will soon learn better.

Animals that haul out are those which pull away from each other while in the yoke or when working as a team in collars. This is usually highly irritating to the team because one will pull the other or put more work upon its friend, forcing its friend to pull hard in the opposite direction to remain standing. Besides being embarrassing to the farmer, the team is wasting energy that could be used for pulling. It is usually caused by one animal feeling like it is too close to its friend and long training sessions getting the two animals to be more comfortable with each other will cure it. Sometimes, in bovines, it is because their horns are poking each other: this is cured by either spacing the animals better or by trimming the horns. Sometimes, the animals learned the behavior while walking on pavement, mud or ice, and don't realize that they don't have to continue compensating for the slipping surface. This is cured by training on good, level ground, and gently teaching the

animal to walk correctly. Sometimes it is cured, no matter its cause, by switching which side the animal works on (which, depending on how well the farmer has trained them to work on either side, may be easier said than done), or by tying the two animals together at their girth strap (when in harness) or by attaching a girth strap for tying the animals together (when in yoke). Often a break from walking on pavement, mud and ice will do the trick.

Turning the yoke happens when the animals turn their rear ends away from each other, spilling the yoke from them. This requires the yoke be attached and reinforces the bad behavior with a rest from work. While strapping the rear ends together helps, tying the bows tight enough to reduce the animal's flexibility to turn within the yoke helps more, and watching your animals and correcting them helps best. If the problem persists, consider switching to harness instead of yokes.

Lying down while working happens frequently with calves and foals when they are tired, but if the habit is learned when young, it is entirely inappropriate when the animal is an adult. Allowing young animals plenty of time to rest between pulls, before pulling and after pulling will reduce the risk of laying down, but adult animals may also lay down because of psychological exhaustion from confusion or fear of severe punishment. Obviously, not punishing the animals severely and providing clear instructions helps. For an animal that is disobedient and lying down to get out of work, you must be stubborn and not let them free until they resume work – at least for a short while. Keep them moving, do not let them lie down. Remember, you must help the animals remember that it is your decision when they lie down. After you keep them working or moving for a short time, tell them to lie down. Sometimes, changing teammates or the side that the animal is working on, or the kind of work the animal is doing will do the trick.

Kicking, biting and horn-thrusting is entirely unacceptable behavior. They may be doing it out of fear or aggression, but an animal that attacks people quickly learns it gets what it wants. Harsh training procedures that encourage an animal to seek its self defense is to be avoided, but if the behavior begins without harsh training, tie or house the animal in a way that prevents kicking, biting or horn-thrusting. Avoid the behavior or stimulus that initiates the attack. Work on basic training, especially touching the animal all over.

Bovines like to butt heads to play, and while this is cute with a calf, it is dangerous with a full grown animal. Do not encourage the calf to butt heads with you. If it needs play, provide a companion calf or other companion animal. Most animals enjoy playing with goats (which also like to butt heads) and llamas, and many chickens and geese make good companions as well. Combining bovines with equines also usually works out. Try playing human games with the animal, such as chasing a ball, "fetch" (make sure you have the animal's favorite treat – and yes, equines and bovines enjoy fetch as much as canines), and learning new "tricks" or taking work "challenges." Hide and go seek with a treat is also great fun!

Inattentiveness occurs when the animals have been trained and handled by many people or have learned that some people do not force them to do what they are told. Some animals can tell one person from another, some cannot, but in any case, the animal starts to develop ideas (hopes?) about all people when one person does not enforce commands. Such animals need positive and negative reinforcement, and a return to basic training.

Sometimes, animals will fight their partner. This is time to switch teammates.

Sometimes, one animal will pull faster than its teammate. You must encourage the slower animal and discourage the faster animal. The slower animal thinks it can get by with less work, and you don't want the faster animal wearing out too quickly.

Grazing in the yoke is dangerous for both animal (they can get tangled in straps, chains or put straining loads on their partner, or upset the yoke, cart, etc.) and quite unproductive for master.

Tying the animal's head up or putting a muzzle around the animal's mouth that allows free air movement but prevents grazing will solve this problem. Some farmers also provide feed bags to the animals while they work, or provide treats at the end of each pass through the field as a way of assuaging the munchies – after all, it is difficult to work among that much good food and not want to take a bite! Having a treat at the end of each pass also helps the animal pay attention to their master against the distraction and temptation of the forbidden food.

Animals naturally challenge your authority, and do not grudge them for this. However, do not tolerate their bad behavior, either: you must dominate them to keep them domesticated. They are not your friend or equal, they are your animal, and the qualities you love them for are the benefits they gain from domestication (greater intelligence, strength and defined personality) are derived from your training.

Weight guidelines for pulling

Plowing and logging are the most difficult tasks a team of bovines or equines can be asked to do. A basic guideline is that a well conditioned team should be able to pull half its weight while logging if permitted regular rests in short hauls, provided that the footing is good and the path is clear. Animals can be expected to get their breath back on their way back into the forest. It is physically possible under ideal conditions for an animal to pull even twice their weight for short distances (a few hundred feet or a few minutes), but animals who do so require significant and regular training and such conditions do not exist on a typical farm.

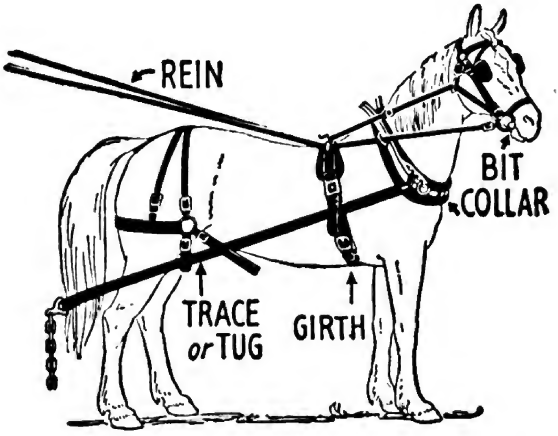
Both bovines and equines use yokes and harnesses

There are an infinite kind of yokes and harness when the home-made articles are considered: the farmer who makes their own makes it uniquely adapted to their needs. Both bovines and equines work in both harness and yokes, but typically bovines will work in yokes and equines will work in harness.

Harness

There are two main categories of harnesses, the breaststrap (or breastcollar, used for light work) and the collar and hames design (used for heavier work). The collar and hames harness places the weight of the load onto the horses shoulders, facilitated by the use of a collar (a kind of modified yoke).

Though a simple harness (as illustrated in the following diagram) has few parts, just as a saddle can be expanded from a seat and stirrups to include other useful and specialized parts, so can the harness be developed.



A simplified illustration of a horse harness with collar (image from Wikimedia Commons)

Basic harness includes:

- A collar to allow the horse to push against the harness with its shoulders and chest. Two main alternative arrangements (with some intermediate types):
 - A horse collar (or full collar). A padded loop fitting closely around the horse's neck, pointed at the top to fit the crest of the neck. Used for heavier pulling, especially when used without a swingletree or whippletree.
 - A breastcollar. A padded strap running around the chest from side to side. Used for light work, or for somewhat heavier work it is used together with a swingletree or whippletree to allow each shoulder to pull evenly on each step without rubbing.
 - Hames (if a full collar is used). Two metal or wooden strips which take the full force of the pull, padded by the collar.
- Breeching (pronounced britching). A strap around the horse's haunches allowing it to set back and slow a vehicle, usually hooked to the shafts or pole of the vehicle. Used for a single horse, a pair, or in a larger team, only for the wheelers (the animal or pair closest to the vehicle). The leaders in a team do not have breeching, as they are in front of the shafts or pole and so cannot slow the vehicle. Breeching may also be omitted in fine harness, or when the cart is very light or has efficient brakes on the wheels.

- Traces or tugs. The straps or chains which take the pull from the breastcollar or hames to the load. Similar to the pull chain of a yoke.
- Girth. A strap that goes firmly around the girth of the horse to attach the harness saddle (a harness saddle is a small supportive piece of the harness that lies on the horse's back and is not the same as a riding saddle).
- Reins. Long leather straps (occasionally ropes) running from the bit to the driver's hands, used to guide the horses. In teams of several animals these may be joined together so the driver only need hold one pair.
- Bridle: When working in harness, most horses wear a specialized bridle that includes features not seen in bridles used for riding. These usually include blinders, also called blinkers or winkers, behind and to the side of the horse's eyes, to prevent it from being distracted by the cart and other activity behind it. Harness racing horses sometimes have a shadow roll on the noseband of the bridle for the same purpose.
- Bits for harness (most often a Liverpool bit) may be similar to those used for riding, particularly in mouthpiece, usually operating with a curb bit and adjustable leverage to help balance the effect of the reins on different horses in a team.

More complex harness will include:

- Harness saddle.
- Belly-band. A strap that goes more loosely under the belly of the horse, outside the girth. Prevents the shafts rising up, especially on a two-wheeled vehicle (where weight on the rear of the cart may tip the front up).
- Back band. A strap going through the harness saddle to join the belly band either side. Takes the weight of the shafts or pole. In cart harness it is replaced by a chain running in a groove in the harness saddle, hooked to the shafts either side.
- Sliding back band. In a two-wheeled vehicle the shafts are fixed to the vehicle to hold it level. On a side-slope, one shaft will be higher than the other, and in this case the back band is normally allowed to slide sideways through the harness saddle, so the horse can walk upright without strain on the harness.
- Fixed back-band. In a four-wheeled vehicle the shafts or pole must be allowed to hinge up and down, to allow the horse and vehicle to pass over hillocks and dips. Often the shafts are independently hinged, and on a side-slope these will each hinge to follow the horse, and a sliding back band is not needed. However, if a sliding back band was used with independent shafts it might allow one shaft to ride up higher than the other, and so for such shafts the back-band is normally fixed to the harness saddle. On other four-wheeled vehicles the two shafts hinge together, and a sliding back band is needed as for two-wheeled vehicles.
- False martingale. A strap passing between the front legs, from the centre of the collar to the belly band, to hold the collar in position. Called 'false', because unlike a true martingale it does not attach to the reins.
- Crupper. A strap attached to the rear of the saddle or surcingle that places a soft padded loop under the base of the tail, to keep the harness from slipping forward.
- Shaft tugs, or just tugs. Loops attached to the back band to hold up the shafts of a vehicle in van or fine harness (not needed in cart harness, which attaches to hooks on the shafts).

- Some horses pulling lighter vehicles, particularly at horse shows and other public exhibitions, may have a overcheck to assist them in holding a desired head position, and for safety reasons. In some cases a specially designed running martingale may also be added. A looser overcheck may also be used in a working harness to prevent the horse grazing. The overcheck hooks to a pedestal on the harness saddle.
- Horse brasses. Brass plaques mounted on leather straps, used for decoration, especially on show harness. Made in a very wide range of designs.

Making harness is easy, the collar presents the greatest challenge as the rest of the apparatus is made of straps, rings and other simple materials. The many non-standard kinds of harness will typically include all the elements of the basic harness because the horse must be able to transfer its energy through a collar to an implement, must be able to receive instructions from its master through reigns and various apparatus must be in place to control the transfer of force and stabilize the equipment on the moving animal's dynamic body.

Harness must be sized to the animal to avoid physical stress and to maximize efficiency, and since most parts of the harness are straps, this is easily done. The collar must be built to fit, however.

Head yokes, Neck (Bow) yokes, and withers yokes

There are several major kinds of yokes, and except for the withers yoke (which is typically specialized to the bovines of the Bos indicus species, especially the zebu with their large withers), the neck yoke is preferable to the head yoke. Equines cannot use the head yoke for lack of horns.

A yoke is nothing but a wooden beam designed to transfer (as a collar would) the force of an animal's effort to a pull chain.

A head yoke is one of the most primitive yokes. A band fits around the bovine's head, tying to a wooden beam that lies behind the poll and horns atop the animal's neck. The bovine then pushes with its head (as it would in a head butting contest) and the force is transferred to the wooden beam. The best head yokes have small notches to hold it in place against each horn, and are designed to allow the animal to hold its head in a downward and natural position, slightly below the line of the back. If the yoke pulls their head too low, they cannot generate maximum power. If the yokes are drawn too high, the animal is uncomfortable and physically stressed, risking injury. Head yokes are efficient, and offer the master good control over the animal, no sores develop from rubbing on the body, and the animal does not choke as with other yokes. However, on uneven terrain, the animals risk great injury.

Neck yokes are not significantly more efficient than head yokes (performing equally as well in pulling contests), but are more popular because they reduce the risk of injury to the animal. They resemble a collar in many respects, and predate the collar (the collar is an improved neck yoke). A beam sits atop the neck, and is affixed by a U-shaped beam (called a "bow") underneath the neck. In some places, the bow is made of metal. The beam is placed atop the neck, and the bow is slid through holes in the beam underneath the neck, affixed in place by pins. Recent developments in neck yokes are making them more and more like collars and it is not unreasonable to presume that in the near future, neck yokes will be given up for collars, or that the collar will be reinvented.

Withers yokes are most common in Africa, India and warm countries where Bos indicus, which has a hump above the shoulders, is used. The withers yoke is a beam that looks much like the

neck yoke, but has no U-shaped bow. Instead, it has two guiding posts (called "staves") on either side of the neck to ensure that it does not slide off to the right or the left without interfering with the shoulders, and the beam presses against the hump to generate force.

In all yokes, when two animals are worked together, the beam is lengthened and stretched between both animals, usually with a notch made to fit about the necks of both animals. The middle of the beam presents the hitch point for the draw chain. These neck seats are rounded, smoothed and sometimes cushioned (like a collar).

When animals are worked singly, the hitching point is similar to the harness, and is found doubly on the right and left sides of the beam, dropping two pull chains like traces or tugs.

In all yokes, the yoke must never interfere with the shoulder. None of the yokes have reins or bits, of course.

Making yokes is easy, but not as easy as making harness as shaping the wood for the beam and bow or staves is difficult.

Shafts should be strong but not heavy, with a solidly attached ring to where it attaches on the yoke or harnesses

Shafts should be strong but not heavy, with a solidly attached ring to where it attaches on the yoke or harness. Some shafts are metal and very strong and very heavy, others are wooden and light and weak. The farmer's discretion is required in choosing the appropriate shaft.

Multiple teams

When working multiple teams (more than two animals at a time), put the largest, most experienced and most powerful team in the front, and the smallest, least experienced and least powerful team in the rear. Besides the obvious benefits of allowing the experienced to lead the inexperienced, it also allows the draw chain to gradually decline towards the object being pulled.

Multiple teams are less efficient per-animal than single teams or single animals, but the combined force can allow large objects to be moved or immense force to be generated.

Never hitch each team to the next team's yoke or collar as this invites injury as the animals are pulled around by their yoke or collar. Attach each yoke or collar by short chains to a main pull chain.

Drive shafts

An alternative to pull chains is the drive shaft, a solid wooden beam to which the yokes or collars are attached by short chains. This is especially good for carting, when animals must also help slow down a vehicle, or for situations when you don't want chains getting underfoot.

Special notes on plowing and other work

It is best if one animal walks in the furrow of the previously plowed ground. This is easily accomplished through training.

Both equines and bovines should not be expected to work more than 3-4 hours per day, and having multiple teams makes sense if the farmer is to get a full day's work.

And, as Jethro Tull warns, it is necessary to muzzle or restrain the animal from eating the crop as you work.

If the animals are to be used in parades, in transportation on public roads or in public transportation, ensure that the animals are accustomed to the work before entrusting them to it: your fellow travelers may, out of malice or mischief, be relied upon to try to spook your animals by making abrupt noises or throwing objects at them.

Packing

For those farmers who cannot afford carts, or who do not have roads suitable for carts, or who desire the convenience of avoiding hitching to a cart for whatever reason, both bovines and equines may be used for packing, that is, the carrying of cargo directly on their bodies. Special saddles are used for this, and while typically equines are used for packing and bovines are not, many of these saddles may be used for either bovines or equines.

Modern packing methods were developed by the Mongolian Conqueror-Emperor Genghis Khan whose army was empowered by the improved speed of pack animals over carts. Improving packing methods with relays and posts, his army was supplied over vast distances with ease.

When the Spanish brought mules to America, it was with the intent of using them for packing supplies over the rough terrain that would not allow wagons. The native American nations quickly improved upon the Spanish methods, having had previous experience packing with dogs, backpacking and haul travois. The English and French are credited with improving upon or inventing the modern pack saddles, panniers and other equipment that are relied upon today: the roads in England and France were not good for wagons, and packing was the only way short of sea transport to ensure a quick and safe transportation of goods. In the United States, pack animals were used most notably for trapping and mining operations in the Western Territories before roads were laid through them.

These days, while packing is primarily a recreational activity, it remains important for the farmer who would not use the roads, who cannot afford motorized vehicles or carts, or who seeks to transport goods efficiently, cheaply and quickly across their farm. Packing is especially important for farms that would rely on animal power instead of tractors for their normal farm operations: though an animal will be used for plowing very often, the use of the animal for packing increases its efficiency and profitability. Animals can be used not only to cultivate crops, but to bring them to the

barn, bins or coolers, and packing allows the animals to work in aisles where carts cannot go. Packing is also very useful for bringing supplies and produce to and from town.

Notes on equines: horses are standard, burros less preferred, mules occasionally preferred

Bovines make excellent pack animals, but some notes should be made on equines as not all equines make equally good pack animals. Horses are standard pack equines, and both heavy and light horses make good pack animals. Burros would be standard pack equines but they cannot carry as much as a light horse: burros require smaller packs. Burros are also slower than horses and mules. Burros also require a packer to walk and lead for the greatest efficiency, whereas horses readily lead from a lead horse. Mules are sometimes difficult for some masters to work with, but eat less, drink less and carry similar amounts to large horses. Some people love mules and swear by them, others hate mules and swear at them. Only experience will tell you whether you like mules or don't.

Notes on llamas

Llamas are becoming very popular and for good reason. They carry less than a burro, but are more sure-footed in rough terrain, eat less than burros or horses per bulk and weight carrying capacity, similarly drink less, and llamas produce valuable fiber which is harvested as wool would be. They are generally as easy to lead and pack as horses.

Notes on cargo

Packing cargo should obey the rules of common sense. Put heavy items on the bottom of the back or as low as possible on the animal to keep their center of gravity close to their feet: this reduces the risk of the animal falling over, or of the pack moving around on the animal's back while packing. Light items should be packed on top for similar reasons. Breakable items should be attached in separate bags to avoid crushing, or enclosed in metal containers. Items that will be used during packing to clear trails (such as axes or shovels), or during the day (such as a camp stove for making lunch, or lunch itself, oats for the animals, weapons for defense, etc.), should be lashed on to be easily accessible.

It makes sense to enclose items in panniers (which are large bags that hang on the sides of the animal to enclose many items) and also in purses (which are small bags to enclose a single item or two).

It also makes sense to load the animal with equal weight on each side so that they do not topple over and so that the load does not shift around while packing and cause injury.

Load your animal last thing before breaking camp or leaving the farm, and unload the animal first thing upon arrival.

Practice tying ropes into knots on the animal before actually loading the animal with something heavy or important. Never at any time get tangled in the rope while it is attached to the animal: a packing expedition should not be an impromptu rodeo and if, for whatever reason, cargo were to shift or the animal were to spook and you were tied up with the cargo and the animal, you would be severely injured.

If packing where there is no water or food for the animal, pack enough for the animal as well.

Potential injuries to animals and people from working animals I: bandages, wild and natural antiseptics, pain relief and swelling reducers. Diluted juniper berries, black pepper, cinnamon and other common herbs are antiseptics; the parts of willow, aspen, cottonwood and other poplars are good for both pain and swelling reduction. Bind both antiseptics and pain relief / swelling reducer in with the bandage. Willow, aspen, cottonwood and other poplars may be ingested and bound to the injury.

Potential injuries from packing for the animal or master are many. However, some are more frequently seen than others. First, notes should be made on bandages:

Bandages should be of clean material. Gauze is preferred, but clean cloth has been used successfully for many thousands of years. Soft, clean, absorbent plant materials are also acceptable. They should be bound preferably with adhesive tape, but straps or ropes work well, too. Supple tree twigs also work well too. If using sphagnum moss, be sure to treat it with antifungals before use as it can harbor dangerous fungal diseases. Boiling for 3 minutes (or steaming with exceedingly hot steam) will reduce the risk of this infection, but be sure to dry out the moss before use.

Cloth and water is sterilized by boiling for more than 3 minutes. Warm cloth can sometimes reduce swelling.

Bandaging with antiseptics (whether it is antibiotic petroleum jelly, diluted juniper berry paste, black pepper, cinnamon, garlic, etc.) reduces the risks of infection and thus bandages should include an antiseptic – especially if an open wound is present. Even if there is no open wound, a bandage can result in fungal infection or worse due to the increased moisture and heat on the skin, which will not be able to breathe as easily with the bandage on.

Many common spices are antiseptics, either because of the properties of the plant from which they originated, or their natural acidity that acts against harmful microorganisms that would eat the proteins of you or your animals (i.e., the cells and tissues of you or your animal).

Pain relief and reduced swelling also does not go amiss, and having the animal (or person) ingest the parts of willow, aspen, cottonwood or other poplars in tea or as a raw vegetable will improve comfort while reducing swelling. Besides ingestion, the parts of willow, aspen, cottonwood or other poplars can and should be bound in the bandage with the antiseptics. The inner bark, the young green twigs, the leaves and other green parts of these plants are the most active parts.

Trees in the willow family, including willow, aspen, cottonwood, and other poplars all contain salicin. Salicin is very similar to aspirin chemically, and has a similar effect on the human body. However, it is better than aspirin in many ways: less is needed as it has higher bioavailability and does not so easily result in gastric bleeding if taken in excess. When consumed, it is metabolized to salicylic acid.

Besides pain relief, look to these plants as relief from itchy bug bites, too! Willow trees (Salix spp.) are found around the United States, typically in moist areas such as along stream banks. Most species have colorful twigs of yellow, orange, or red. They have narrow leaves, arranged alternately with no terminal leaf. Their flowers are catkins and their fruits are small, tufted seeds.

Aspens (Populus tremuloides) grow across the United States in moist soils and along streams. The bark is white with black scars and has a yellow powder on the surface which you can see if you wipe it on your fingers (it can be used as a sunscreen or as a yeast for bread). The leaves

are round with a pointed tip, the flowers are catkins. Cottonwoods (Populus fremontii and Populus deltoides) are found across the United States in moist areas. Their gray bark has deep vertical grooves, the leaves are triangular or diamond shaped, the flowers are catkins and the fruits are fluffy seeds that look like those on a cotton plant.

To make use of the aspirin-like qualities of these trees, there are several methods of preparation. If your pain is internal, you can eat or make a tea from a small amount of the leaves, leaf buds or cambium (inner bark). To eat, you can swallow it, or (for those with weak stomachs) chew and spit.

If you pain is external, chew the leaves, leaf buds or cambium and apply the pulp to the sore area (if you have use of kitchen supplies to make the pulp, go ahead and do so—chewing is a good emergency preparation, but is somewhat inferior to a kitchen blender, mortar and pestle, or juicer).

Another popular preparation is to soak the leaves, buds and cambium in olive oil, vodka, rum, or your favorite non-toxic solvent. This can be used as a salve on the surface of the body, or drunk for internal relief.

Along this vein, the pulp can be sweetened and dissolved in your favorite solvent to improve palatability further, though this is likely unnecessary as the trees don't actually taste that bad. However, a little bit of sugar always helps the medicine go down!

These trees usually have decent firewood as well, and the warm water they can help you make will also ease pain and reduce swelling. Or cook a decent meal. They also are good for shelter. What wonderful plants!

Of course, always consult a doctor before using any medicine, be careful to identify plants properly before use, and check for allergies or bad responses before applying a full dose of the medicine. Also, be aware of local laws before harvesting public trees, and if harvesting on private property, gain the permission of the landowner. That said, in most locations in America, public trees may be used by the public without permission, but it is better to double check with the local government or Federal administrator beforehand.

That said, the farmer is wise to plant some willows, poplars, junipers and other useful and medicinal plants against the risk of an emergency. Preserving the harvest in various solvents increases portability.

One of the best solvants to preserve them in is an ointment. Submerge and soak the herbs (preferably the medicinal herb with one or more antimicrobial herbs) in oil for at least a day. Some people will soak the herbs for months! When it has reached the desired strength, warm the oil and add in quantities of beeswax or other wax to thicken it to a consistency that will allow it to be smeared on skin or dissolved into ingestible teas or eaten straight. If it is to be eaten, the ointment should be flavored. Avoid using sugar, as it could result in spoilage. The addition of vitamin E to the ointment will somewhat preserve the ointment against rancidity. It helps to take a spoonful of the heated ointment and let it cool to see how thick it is at room temperature. Add more oil or wax to thin or thicken it as necessary. Pour it into jars for portability.

Potential injuries from packing II: identification and treatment

Saddle sores and cinch gall are warm, raised plaques or raw bleeding ulcers. They are caused by improper adjustment, poor fit, or dirty equipment. Keep your equipment clean, well fitted, well balanced and you will never see this. When not actively packing (usually at night), unload the pack animal and groom them. Inspect for any sores on the back and clean the wounds, allowing

them to air and heal over night. If possible, bandage or pad the wounds in the morning when packing resumes. Reduce swelling. Use a thick blanket underneath the saddle: even two blankets would not go amiss. Keep your saddle tight through the day so that it does not shift around and damage the animal's skin. Keep your blankets and equipment clean!

Rope burns occur when the ropes or straps rub on the skin enough to damage it and are very painful. Again, clean, well fitted equipment reduces or eliminates the risk of this injury. Remove the hair away from the burn and bandage. Antiseptics are recommended, as is extra padding. In an emergency, raw butter or raw milk may be rubbed on the wound often: the raw milk is antiseptic and if applied in butter form, also reduces rubbing on the wound.

Stone bruises and foot punctures occur when the animal walks on sharp stones, sticks or other hazards and damages their foot. This will require reducing or eliminating the animal's pack load and a bandage applied to the foot for extra padding as they walk. While some manufacturers will vend "easy boots" (which are rubber-soled slippers for horses similar to human tennis shoes), a device may be improvised out of rags and straps. If any of the sharp object is embedded in the foot, remove it carefully and bandage, ensuring that both something to reduce the swelling and an antiseptic is bound in the bandage. If the object is embedded deeply and the animal can walk, wait to remove it until a veterinarian can be consulted as removing it might result in severe damage – but use judgment and common sense in deciding to wait.

Wounds to eyes: these are serious conditions that require immediate attention and can result in blindness. Gently flush the eye with a (very diluted) antiseptic every four hours. Bandage the eye gently and keep away from light, dust, and wind.

Insect bites are usually inconveniences, not injuries. However, they can become infected, or result in a severe allergic reaction. If an allergic reaction results, treat the swelling.

Snakebites are potentially very serious, if not for the direct death that may result from the poison, than from the swelling that may shut off airways or blood vessels. First, bind the area above the bite to reduce the flow of the poison towards the heart. The puncture site should be sucked clean: many medical kits include suction devices so that the person applying the treatment does not risk poisoning themselves by sucking it out with their mouth. Puncture the area with a sharp knife to encourage bleeding and drainage before, during and after attempting to remove the poison. During swelling, puncture the skin and tissue and apply pressure to reduce swelling. If the gums of the animal or person turn from pink to blue, they are suffocating and an emergency tracheotomy may be necessary to save the life of the animal or person. While training in this difficult procedure is definitely suggested, it typically involves making an incision into the tracheal ring just above the collar bone in the neck into the trachea. A disposable syringe is useful for this, as it can serve as a temporary airway. Due to risk of death, tracheotomies should only be used as a last resort. An alternative is to stick a rubber hose up the nose and down the trachea. A hose should certainly be used if the animal is bit on the nose and cannot breathe through it anymore because of swelling.

Horses are famous for their inopportune attacks of colic. While there are many manifestations of the disease and a veterinarian should be consulted quickly, if the animal has decreased appetite, anxiety, sweating, pawing, rolling, odd abdominal sounds, rapid pulse and respiration, kicking at belly or other symptoms, keep the animal warm and walk the animal only enough to prevent them from injuring themselves. Allow the animal to lie down if it will do so without rolling. Give the animal something for the pain (such as willow or poplar), but whatever is administered should be VERY easy to ingest: a tea poured into the animal's mouth would be best.

If the animal's hindquarters are stiff and hard, and is urinating very dark brown or red, the animal has tying up syndrome and should be rested immediately for about 12 hours. They are overworked. If the animal prefers to lie down, the situation is very serious.

If the animal has extreme pain in the feet, they have founder and are overworked. Reduce or eliminate the work of the animal and have a vet see the animal immediately.

Lacerations, punctures and other wounds will likely require a trip to the veterinarian (or doctor, if a person!). Some, but not all, wounds require a trip to the vet. But minor (and some not-so-minor) cuts and scratches can be easily cared for at home. Follow these steps to healthy healing!

1. Inspect the Wound

Examine the extent of the damage. Do not go by the amount of blood—it is usually difficult to tell how bad a wound is by how much blood is coming out because a little bit of blood may seem like a lot, sometimes a shallow wound may bleed very badly and sometimes dangerously deep wounds don't bleed much.

Regardless of whether a vet is required, you will likely need medical gauze. However a cheaper alternative to gauze is women's hygienic cloths or rags: these are the same thing, but have the advantage of price and an adhesive to hold it in place!

Do you need to call the vet? Ask these questions: if any are a "yes," call the vet!

Is there is hanging flesh, or visible bone? Before calling the vet, immediately cover it with sterile gauze.

Is there splurting blood, as if an artery has been cut? Before calling the vet, immediately apply pressure to the wound with an absorbent, sterile gauze.

Is it a puncture (punctures may look ok at the surface but actually go deep into a joint or other vital structure). The vet may ask you to perform secondary inspections to learn if more than just the surface has been damaged.

2. Clean the Wound

Wash away dirt, hair and other debris by holding a hose or a glass of water above the wound and letting the running water flush it clean.

If the animal's fur or hair is long and in the way, trim it back with scissors. If any large debris does not wash out, remove it by hand (after washing and sterilizing your hands) or with tweezers (do not scrub the wound).

If any debris is embedded? Leave it in place and call the vet!

3. Inspect the Wound Again

Inspect the wound again. Even if it looked ok before washing, it may turn out that now that it is clean, you can see that it is actually worse than you thought.

But, it might be better than you thought, too, so it is good to check and make sure.

So, go back to step 1, and if everything answers "no," go to step 4.

4. Sterilize and apply antibiotic

Now that it's clean and looked at twice, rinse the wound with rubbing alcohol, betadine (10% iodine solution), or your favorite antiseptic. We do not advise hydrogen peroxide, as it may cause tissue damage.

Then, apply antibiotic spray or cream. While Neosporin or other antibiotic petroleum jellies are good, choose one that is nontoxic or that is designed for animals or very young children: it is likely that the animal will play with the wound. If possible, apply an anti-fly wound treatment.

Depending on the animal, a bitter-tasting ointment designed to reduce biting and pecking by the animal's friends would not be out of place here, either.

5. Wrap it Up

If possible, cover it with gauze and use "vet wrap" tape to hold it in place. Vet wrap is self-adhesive and won't stick to hair, fur or skin. Regular tape will also do.

Do not apply it too tight or you could cause serious problems! If you don't know how to apply it, or need help covering a wound that is in a complicated location, call the vet!

6. Change Bandages Daily and Watch for Infection

Change the bandages at least once per day and watch for signs of infection. Examine the wound at each change.

Is it swelling? Is it hot (warm is ok and natural, but hot could spell infection brewing). Is it developing puss or other fluids? Is the scab forming unusually or not at all? Is it continuing to bleed?

If the answer is yes to any of these questions, call the vet!

Pack Saddles

There are two usual kinds of pack saddles, and while there is infinite variety in home-designed articles, all pack saddles will typically include elements of a Girth Strap, a Crupper, a halter or other device by which the animal may be led by a person or attached to a leading animal, and specialized packing straps or saddles to which cargo may be attached. The use of halters (which are nothing more than ropes tied around the animal's head so that a leading rope or reins may be attached) is nearly essential to packing because the loaded animal cannot be ridden (except with the bareback pack saddle) and the master must typically ride a separate animal, or else the trails in which packing is used require the master to walk in front of the packed animal. Some masters will tie a slipknot around the neck of stubborn animals instead of using a halter and while this will encourage the animal to keep up, it is not safe for animal, cargo or master in the long term.

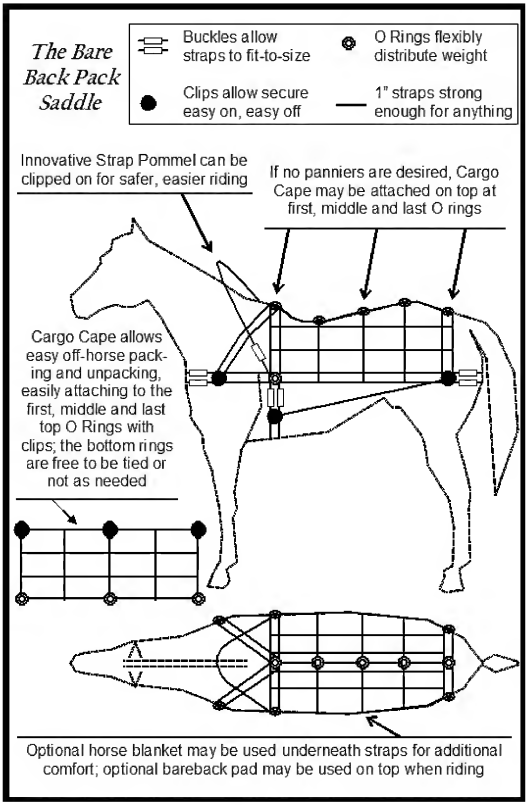
Commonly, a western saddle is used for packing by employing the pommel as an implement to which bags may be tied.

An improvement to this is the sawbuck pack saddle, which has the specialized components of two or four modified pommels, made of wooden beams that are crossed in an X above the spine of the horse (and are themselves mounted to a saddle). This facilitates better tying than a pommel, and distributes the weight very well across the back of the animal as the pommels project the weight through the saddle across the entire back. However, if the pommels are not constructed well, this saddle can result in grave injury to the animal.

Sawbucks can be made, besides from lumber, with elk, deer or bovine horns.

A deckers pack saddle has no pommel or modified pommel, but does have wooden boards or canvas sheets on either side of the horse on which is attached straps to which bags may attached. Several straps across the spine improve weight distribution. The deckers saddle does not pose nearly the risk of injury that a sawbuck saddle does.

We have designed an improved deckers pack saddle which allows for the better weight distribution of a sawbuck and the safety of the deckers, illustrated on the following page.


The Bare Back Pack Saddle
Buckles allow straps to fit-to-size
O Rings flexibly distribute weight
Clips allow secure easy on, easy off
1" straps strong enough for anything
Innovative Strap Pommel can be clipped on for safer, easier riding
If no panniers are desired, Cargo Cape may be attached on top at first, middle and last O rings
Cargo Cape allows easy off-horse packing and unpacking, easily attaching to the first, middle and last top O Rings with clips; the bottom rings are free to be tied or not as needed
Optional horse blanket may be used underneath straps for additional comfort; optional bareback pad may be used on top when riding

The bareback pack saddle also has the additional facility of allowing packing while riding, without the use of uncomfortable (for the rider) saddlebags, and can double as an affordable riding saddle thanks to the strap-pommel.

Use panniers and purses and tie or clip bags directly to the saddle, notes on waterproofing

Essential to packing and most work on the farm are ropes and knots. While they are very useful, we do not recommend them as the primary means of attaching cargo to the animal if panniers and purses are available. It is far easier to access an item during the packing trip if it is in a bag than if it is intricately tied up with the other items in the cargo, and it is much easier to tie a bag to the saddle than it is to tie bags or other cargo to the back of the animal. Panniers present a more modern and useful method.

While one method of packing with panniers involves loading light baggage on top of the panniers and netting the entire outfit together, it is easier still to strap the lighter cargo directly to the saddle with the panniers.

Bags may be tied to the saddle, or they may also be clipped. Many useful clips will function fine, just be sure to check how much weight the clip is warranted to carry before overloading it. If in doubt, use two clips instead of one to disperse the weight. The same warning goes for bags: do not overload bags with cargo too heavy for it, or the bag will rip. Double bag, or disperse the cargo among several bags. You can also enclose several heavy purses in a pannier, which is like double bagging it.

The importance of waterproofing bags is dependent on the cargo carried and the anticipated weather. While oiling canvass, or using plastic, nylon or other synthetic bags will keep items more dry, it is important to remember that no bag is actually waterproof. Water will get in somehow. Even a hard container designed to hold water (such as a canteen) trusted with something that cannot get wet may fail if the temperature and pressure conspire to condense dew in the container. And do not forget that the animal may sweat through your bags, the saddle and the blanket! It is best to waterproof bags as much as possible, but to understand that things will need to air dry occasionally.

Tying animals to each other during packing and other trail notes

Some masters will tie their animals together nose to tail, tying their leading animal's tail into a "pigtail" by binding it into a loop and then tying the following animal's halter to the loop. This is dangerous to the lead animal, especially if the following animal does not like to keep up, if you are packing on rough terrain where a following animal may slip and fall, or if one or both of the animals should spook for whatever reason. It is much better to have all the animals held by the master, whether the master is riding or walking.

However, with very long trains of animals, this is not always possible, and if animals must be tied together, it is best to tie them together nose to saddle. An improvement to this is to run one or two very long leading ropes along the sides of the animals, attached to the saddles, with short attachment ropes from the long rope to their halters. This set up resembles a multiple-team harness, the difference lying largely in that the master is leading the train from the front instead of driving them from the rear.

Some masters will tie a slip knot about the neck or head of the following animal, encouraging it to keep up. But, this is very dangerous for obvious reasons.

If one of the following animals begins to slip off the trail, spur the lead horse forward to have the entire team help haul the falling animal back on to the trail. If the master is holding the leading rope while riding, affix the leading rope to the horn or pommel of the saddle to have the horse they are riding help with the pulling.

If turning around on a steep or narrow trail, turn the animals around so their heads face away from the drop, otherwise they will spook.

If a tree has fallen on the trail, either axe a wide enough opening for the animals, or use your shovel to build a ramp over it. Be sure to encourage each animal through the gap in the log or over the ramp as it will be terrifying to the animals.

Bells and other camp notes

If you must pack overnight, it is a good idea to attach bells to the animals so that you can find them if, for whatever reason, they escape camp during the night. Different bells for different animals allow for identification of which animal is where while you are sleeping. To prevent escapes, tie animals to a tree, a stake or hobble them. If you do feel inclined to turn your animals loose for grazing, do not turn all your animals loose to graze at the same time, but retain enough for every member to ride on in case a round-up is required. It is occasionally necessary to bring feed for the animals if the natural pasture is poor.

Be sure to tie all food out of the reach of bears (suspended from a tree more than 10 feet above the ground), and far away from the pack animals. The sort of animals that would be interested in your dinner are not the sort of animals your equines or bovines want to meet. If you're using llamas, it is likely you can avoid this inconvenience, as llamas frighten and intimidate most wildlife... but better safe than sorry. Beware of squirrels, as they will rip your bags to get at your food and there is not much you can do against them except to try to reduce any smell of your food, lace your bags with chili powder or other deterrent, or employ metal containers for your food instead of bags.

Always keep halters on the animals so that they are easy to catch and lead in an emergency.

Riding, stirrups and saddles

Both bovines and equines may be used for riding, though bovines are significantly less comfortable to ride than equines because they are so wide. However, the use of platforms on the bovines (similar to those used with elephants) or other modified saddles can improve comfort. This said, there are those who enjoy riding their animals bareback.

An animal trained in directional commands who is used to packing or pulling in harness, yoke or saddle easily learns how to carry a rider. Some animals enjoy carrying their master, others are disturbed by the novelty of it. However, once used to the idea of it, the animal will quickly learn how to ride.

An especially important command for those wishing to ride their animals is the "stay" or "don't move" command, which is useful when mounting the animal.

The stirrup, while not essential to riding, is the most useful tool for the rider. A stirrup is a light frame or ring that holds the foot of a rider, attached to a saddle by a strap or else hung in pairs over the back of the animals. The strap is called a stirrup leather.

Stirrups aid in mounting and act as a support while using a riding animal, and are especially useful when the rider is carrying weight, needs to stand on the animal or is being pushed off during warfare or training exercises. In fact, they not only increase the rider's ability to stay in the saddle or atop the back of the horse (if riding bareback), but they also help the rider control the animal by aiding in communication: the rider is then more easily able to communicate with their mount by their legs and heels.

Using legs and heels as a goad, the rider may squeeze, tap or gently kick the animal's sides. The use of a spur (a foot-mounted goad) on the heel increases the ability of the rider to communicate through this method.

The earliest stirrups were invented in India in about 500 BC and were a simple toe loop made of straps used for a mounting aid. Later, after the invention of the treed saddle, the modern stirrup was developed. Though the invention of the modern stirrup is credited to the Chinese Jin Dynasty, supposedly coming to Europe during the Middle Ages, it is likely that the stirrup was independently developed in Europe, Africa and other parts of Asia and there is not much evidence to support the Chinese claim, especially considering how so many nomadic peoples of western Asia used stirrups, and the Indian invention of the primitive stirrup. In any case, in the 7th Century AD Charles Martel, a Frank and the grandfather of Charlemagne, recognized the military potentialities of the stirrup in time to defeat the invading Muslims in the 732 Battle of Tours, singlehandedly halting the expansion of Islam into Europe. Martel so much believed in the stirrup that he distributed seized lands to his retainers on condition that they serve him by fighting in the new manner. The Japanese improved upon the stirrup considerably, by molding it to a rider's foot and making it more like a shoe to perfect the rider's balance. Some had holes in the bottom to allow drainage of water gained by crossing rivers, and others had sockets for the stabilization of spears, lances, flags, and posts of various sorts. Europeans made similar advances through the innovation of the riding boot, a shoe intended for the stirrup. Modern stirrups have such specializations as hinged bottoms to allow the rider to angle their ankle for better balance, safety features that allow a foot to fall away so the rider is not dragged, some models allow riding with one foot only and standing or sitting on the side of the horse (side saddle, a style of riding perfected by the Lakota Chief Tȟašúŋke Witkó ("his horse is crazy" or Crazy Horse, who could ride on one side of his horse so low he was invisible and unable to be shot by his enemies), and many other conveniences and inconveniences.

Modern stirrups come in a wide variety of styles, sizes and materials. The stirrup should fit the rider, and much is left to the rider's preference for materials, shape and size. There are still safety concerns associated with the use of stirrups, including a risk that a fallen rider may get their foot caught in the stirrup and be dragged by the horse, or that long hours of use without rest may cause problems in the human foot's Peroneus Tertius tendon.

There are three principle saddles: the Western, the English, and the bareback.

The bareback saddle is typically a blanket or formed cushion that is strapped on to the back of the horse by a girth strap. It is the most ancient form of saddle, and still is quite effective and comfortable. The modern saddle was developed in the Middle Ages to offer greater support to mounted warriors and led to the innovation of the English saddle. The English saddle has no pommel to speak of and is not much more than a stiff shaped bareback saddle. The ancient saddle of the middle ages also evolved into the Western (or "stock") saddle, which has both an exaggerated pommel and cantle (a kind of small back rest). In many places, the Western Saddle also has a horn on the pommel to assist in packing, and especially in the anchoring of ropes used for lassoing cattle.

The Military saddle is a modified English saddle, intended to be more flexible to conform to a horse's shape as it gains or loses weight during a campaign, or in case it must be used with a different

horse entirely if the mount is killed. Northern Asian tribes have developed their own saddle, but its resemblance to the Western saddle requires little further remark.

The trend is currently towards developing more flexible saddles (akin to the Military saddle), as it is more comfortable for the horse and reduces the risks of injury. A retrograde trend away from saddles to bareback riding has been apparent as well.

Helpful tips for traveling through rough terrain

When going out to harvest, especially in cold weather, remember to bring warm clothing. Wool is an ideal material for your hats, gloves and other winter clothing because it stays warm even when wet!

Stay aware of how much time you have before sunset. By extending your hand at full length, you can estimate how many hours and minutes you have before dark: every hour, the sun travels across the sky the distance between your thumb and your little finger. So, if the sun is one "hand" above the horizon, you have an hour until sunset. If it is two "hands" above the horizon, you have two hours before sunset.

If you are caught out after dark, or simply want to cook some of the delicious things you have found, you'll want a fire. Of course, you may have had the foresight to bring a portable stove with you (one can be easily made by two tin cans: a small one to hold the fuel, and a larger one placed inverted on top of the smaller one with holes for ventilation poked near the top allows a pan to be rested on the top of the larger can. Cutting a hole to ease the insertion of wood chips to the holder-tin is a mark of excellent foresight). However, if you have not, dig a fire pit.

Fires made on top of the ground use more fuel and burn colder than fires made in a pit. One excellent fire pit method is known as the "Dakota Fire Hole," which is nothing more than a pit dug into the ground and a lateral hole that, exiting the pit parallel to the surface of the ground, allows air to come into the pit. A pit about 12 inches deep and not much larger in diameter is usually quite sufficient, but some people like larger fires. A variation on this is the fire cross, which is two trenches dug at perpendicular angles into a central pit: the four spokes help with the ventilation of the fire. These fires can consume not only wood chips, but small branches, burn hotter with less smoke and burn below the sight level of the ground (which make them nearly invisible).

If you are cold at night, try warming stones by your fire and – before they get too hot – putting them next to your sleeping bag (or in it for a toasty treat!). Build two fires and camp between them. Or, build a large fire trench (about as big as your body), line the bottom with stones to absorb the heat, get it roaring hot and then cover it up again. Then lay down on the warm bed. If it is too warm, line it with bedding. If you have a blanket, lay on it diagonally, cover up your feet first, fold one corner over your legs, the next corner over your chest, the third corner over your head and the last corner over your arm that has just covered up your head.

Pine trees provide superior bedding and blankets too. Cutting some branches off and laying on them keeps you off of potentially wet snow or soil, and covering your body with them shields you from the wind and insulates your body.

If the weather is inclement and you want some shelter from the rain or snow, construct a tripod out of tree branches and then, when it is stable, lean more branches around the cone's top to make a tipi. Then, lean pine or other braches against the frame: point the branches with the terminal end of the branch downward and the leaves or needles will shed the water on the outside to keep you dry. If built well, they can last several years. Don't forget to leave open a small hole to enter and

exit. With extraordinary care, a SMALL fire can be built in the tipi. Make sure to leave a vent in the roof for the smoke.

But, a serviceable structure can also be built by leaning the frame against a tree or a rock: this will produce not a cone, but some other shape that organically blends with the support it is based on. Choose something that won't let the water in from the "back" of the shelter! If you use grasses or sod instead of tree branches, remember to point the vegetation down to keep the moisture out of the inside. Grasses will require branches on the outside as well to keep them weighted and not blowing away.

You can, if you have the time, also hammer into the ground four posts at nearly right angles, lash them together with small branches or rope, put a cross beam between them and layer other branches along the side to make a very sturdy A-frame.

You can get warmed up quickly if you utilize some of the natural vegetation in the area as insulation, both in your clothing and in your shelter. By stuffing your clothing and footwear with insulating plants you will make even the lightest of shirts feel like a warm winter coat. Stuff your pants and shirt with any light fluffy fiber you can find in the area (check for bugs first!). Cattail down, thistle down, dead leaves, dead grasses, even bark fibers will do well. What you are trying to do is cut down on the wind passing through your clothing and make dead air space to warm you up. By tying off the bottom of your pants and the sleeves of your shirt you will be better able to hold in your stuffing. Besides your tree branch blanket, also consider giving yourself some soft leaves, grasses or down to sleep on and beneath. Make sure that where your shelter meets the ground there is no way for the wind to come through and steal that hard-won heat that your body and your SMALL fire has produced.

The best kindling for fires is, of course, a candle: candles can hold the flame long enough to ignite even damp twigs. However, collecting the fluff from cattails or cottonwoods, or the dry pine needles you walk by, or other small, easily flammable materials is never a bad idea. Feed your fire slowly: very gradually increase the size of the fuel that is fed.

When making a fire on snowy ground, the fire pit method may not work: the ground could be too wet, or too frozen. In this situation, you will need to make a platform on which to build your fire. Layer wood on top of the snow and construct your fire on top. To shield it from the wind (as in a fire pit), you can stack wood around the fire to make a sheltered above-ground "pit."

President Theodore Roosevelt learned an important lesson while on his many expeditions: beans and other food take a long time to cook. It is best to cook them overnight so that they're ready for breakfast. Then, pack dinner along so all you have to do in the evening is warm it up! He relied heavily upon the foods he could find along the way. Yet even he packed along some of his favorite things: oatmeal, rice, beans, dried fruits, sugar, coffee, tea, salt, some chocolate, and some bread, biscuits and gingersnap cookies (which certainly did not last long, nor could have if they had not been consumed quickly). Roosevelt preferred hammocks and bug nets for his sleeping, but we prefer sleeping bags. To each their own! If you use a tent, make sure that it is well ventilated if you are using any flame to heat it. Carbon monoxide poisoning and the resulting death, while painless, does cut down on your wild harvesting fun.

Storing food sometimes means keeping it dry. A good container for keeping water out is one that is designed for keeping water in. Canteens are excellent for storing your favorite dried wild foods, flours, grains, beans, spices, sugar, dry coffee, dry tea, or other things that make your wild culinary adventure better.

Before you break camp, you'll want to clean your pans and dishes. But you forgot soap and there's no yucca or other soapy plants about you! Don't worry, you have plenty of ashes from your

fire. The ashes, when combined with the oil from your food (add a little more oil if you need to – a drop or two to several cups of ashes will do wonders) makes a great soap. Make very sure that you did not burn any plastic or toxic materials in your fire or the make-shift soap will be toxic. A similar precaution should be made against using unclean water: boil water, and use water that you believe to be free of pollutants or other toxins. Wash your plates and pans 200 feet from any pond, river, stream or other water so you don't contaminate the water. The wood ash soap is very harsh, so we don't recommend using it to clean your body except in extraordinary emergencies. Hardwoods make better ashes for soap than softwoods. Using hot or warm water to clean with makes everything easier: your soap will be a paste, and you will want the hot water to help everything get well lubricated. Let the paste sit for a few minutes to allow the magic of chemistry to occur: the hot water will create potassium salts from the wood ashes, which will then mix with the fats or oils in the food residue to make soap. Stirring helps. And, don't soil your newly cleaned equipment by rinsing them in dirty water: boil clean water for rinsing!

Be very careful with ash soap. You can damage aluminum or other metal pots, and seriously damage your skin. Ashes mixed with water makes lye. Lye is Sodium Hydroxide. NaOH As a solid, the Na and OH are bonded and unreactive. When you mix with water, you break the bond and Na^+ and OH^- are free to react with anything and everything they touch. When mixed with oil, soap is made.

But what if you forgot your mess kit? Prepare your fire pit as usual and keep an eye out for a large stone or rock. If it has a nice flat side, all the better. Warm it up in the fire or, if possible, suspend it over the flames by changing the shape of your fire pit. You may need to raise it above the flames to prevent suffocation of the fire by suspending it on top of several small stones, but maybe not. Cook on the warm stove. This also reduces the need for clean up later.

Definitely purify your water – no matter how close to the source (even if it is at the spring itself), no matter how clear, presume the water is toxic. Microorganisms are so tiny that they are invisible! Better boil the water to make sure they're dead so that you won't die yourself. Be careful when bathing: that beautiful water might have been rolling over the diseased, decaying carcass of a not-so-recently killed deer. Purify water for cooking and for bathing: bathing out of a pot with a washcloth is not much fun, but it beats a skin, eye, ear or other infection every day of the week. If the wind is cold on your wet skin, set up a wind block by hanging cloth, a tarp, or constructing a shelter out of tree limbs. Bathe quickly. With warm water. You'll warm up afterwards near your roaring fire.

Besides boiling, you can stir air into your water for a minute or more: the oxygen will help purify some of the chemicals in the water. Direct sunlight for 6-8 hours (as long as your water basin is not very deep) will help more – the UV and other radiation will break down toxins. Evaporating the water and condensing the vapor will also reduce toxins, but as some toxins will condense with the water, this is not fail-proof.

If you do have to drink out of shallow water, try not to disturb the bottom of the water. The clean water from your trickling spring, creek, etc. will become even more contaminated than it already is. Use a cup, or improvise one with bark, or a clean hollow stone. Many edible plants have hollow stems that work wonderfully as straws. Do purify the water, though, if possible.

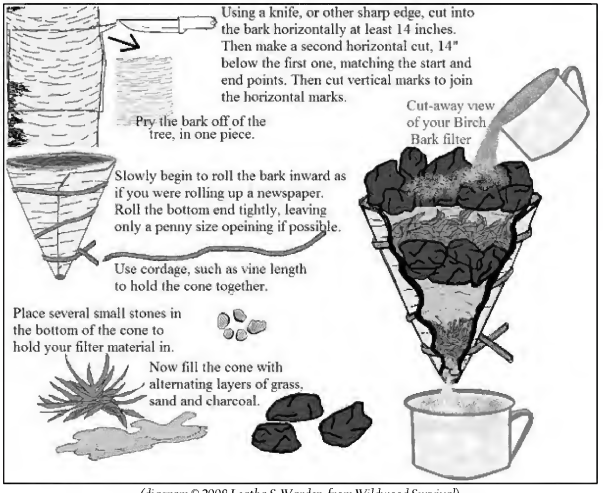
If you don't have a handy pond, river, creek, spring or other source of groundwater, consider the local vegetation. Edible trees such as walnut, hickory, birch and maple have nice liquid sap, many cacti have good liquid in their pulp. Thistles, sunflowers, many delicious roots – all have water. Pulp these plants if you can, or put them in your pot and warm them: the steam will be caught by the lid of your pot. Lay out clothing, tarps, tree bark, grass, leaves, anything to collect dew

in the morning. Wake up early and save every drop. To collect sap from trees, you can either bore 1/4 to 1/2 inch holes in the trunk and insert a some twig or other thing that will drain the liquid into a cup, or you can cut diagonal slashes in the trunk to help direct the flow. Do not cut all the way around the tree unless you are trying to kill it: many trees are edible, or otherwise useful and it only makes sense to use the tree for water, food, shelter, fuel, sanitation and other purposes if possible.

If you are going to eat snow for water, consider melting it first: there is no need to waste your physical energy melting snow in your belly when you could melt it in a pot.

If you find yourself in a situation where you have a limited reserve of water, conserve your supply to the utmost by following these few simple rules: don't eat anything if you don't have water to drink with it. By consuming food you'll burn up your body's supply of water all the quicker. Travel only during the coolest hours and walk at an easy pace so that precious water doesn't get used up through perspiration. Don't drink urine (unless you've first purified it) because doing so will increase your body's rate of dehydration. And try to store as much water as you can in your stomach. People have died with full canteens as a result of trying too hard to conserve their water supplies! Besides, it is easier to stay hydrated than it is to rehydrate.

The folks atwildwoodsurvival.com have an ingenious way of purifying water from sediment they call the birch filter. "You can make a water filter from a cone of birch bark. This cone is then filled with layers of sand, charcoal, grasses, and other materials. Grasses and sand help to trap suspended particles. Charcoal helps to remove bacteria and such. You may have to pass the water through the filter more than once, depending on the size of the filter and what it's made of. Generally speaking, the bigger the filter, and the more layers you have in it, the better. The birch bark cone will need to have a fairly small hole in the bottom. The cone will have to be tied with cordage to keep it from opening up. Put a few stones in the very bottom, to help hold your filtering materials in place. Then pour in layers of charcoal, grasses, sand, and possibly other materials that you feel will help to filter out suspended particles and perhaps even bacteria. Once you have constructed the filter, simply pour impure water through the filer, catching it in another container at the bottom."



(diagram © 2008 Leatha S. Warden, from Wildwood Survival)

You can also use a "well" method of purifying water: dig a hole about 2-4 feet from a water source, such as a river or a pond. Allow the hole to fill with water. The water in the hole will likely be reasonably pure (but there are no guarantees, though!)

If you want to bake while you're out and about, don't miss your oven too much. You can make several excellent kinds of ovens out in nature. The most basic kind is to heat up rocks very hot by lining a fire pit's bottom with them and burning a fire over them for an hour or more. Remove the coals and cover the rocks with some green bark (you don't want to use soil for this because it will get in your food – make sure to use bark from edible trees!), put your food on top of the bark, then cover it up with more bark or other non-toxic vegetation. If you have a pot, you can also put what you want to bake in the pot and then put the pot in the fire pit, covering it with soil or vegetation. Don't put your pot right on the rocks or you might damage your pot! You can also use two wooden or woven baskets, one on top of the other, or wrap your food in non-poisonous leaves.

To warm water for bathing after your meal, you can use tongs to remove the stones from beneath a fire and put them into a basin of water. This will protect your precious pot from being subjected to direct flames, and get you piping hot water at the same time. Granite and quartz may

shatter when you do this, but won't likely eject any material dangerously at you. Basalt will handle the changes in temperature best.

Sooner or later, you will likely need to eliminate the meal you just ate. If you forgot to bring toilet paper, consider mullen. Or, if mullen is out of season, look to the helpful pine tree again. Its needles are soft, mildly antiseptic and good smelling, adequate for every need after defecation. Also consider soft deciduous leaves, cattails, and other things in season. Burying your waste is important for sanitation – even if you are not remaining nearby your waste, other people might be exposed to it, and animals who are unused to your native flora might be sickened if exposed. So dig a hole at least a foot deep, and bury your waste. Consider, too, that your urine might contain things not usually found in nature: do not urinate in or next to bodies of water, but try to keep 200 feet of soil between you and the nearest water to purify your waste.

Brush your teeth! Dogwood stems can be used as a chew stick or toothbrush, birch twigs can also be used the same way. Juniper twigs and Hercule's Club twigs are great for brushing teeth. Then, gargle of pine needle extract (from soaking pine needles) works to freshen breath somewhat and has some antiseptic properties. Oak tanin (from soaking bark) is also antiseptic.

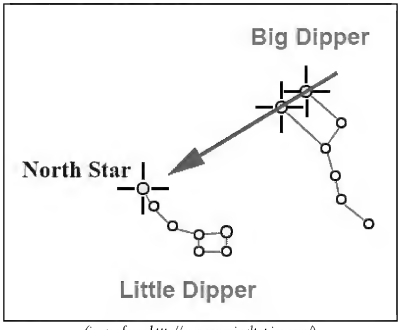
Flossing, or more likely in a survival situation, picking your teeth is almost as important as some form of brushing. Keeping food out of the spaces between teeth as well in the hollows of molars goes a long way. Carve some tooth picks or use thorns from non toxic plants (i.e. wild roses, hawthorns). Or, simply rub clean fingers through the teeth until they feel clean (sound like rubbing a clean wet plate). Also eliminate any food between the teeth with a small, non-toxic stick.

The fun of a day of harvesting can be quickly spoiled by sunburn. Look to the helpful aspen for sunblock if you forgot yours: rub the wonderful powder from the bark all over exposed areas and you'll thank yourself later. Sunburned eyes (also known as "snow blindness") is no fun either, and may lead to blindness. So, bring sun glasses. If you did not bring sun glasses, reduce sun exposure to your eyes: take a thin piece of bark and cut it into a glasses-like shape, poking some holes where your eyes go, or use a bandana to partially blind yourself.

Don't become dehydrated. Drink before you're thirsty. It is easier to remain hydrated than to rehydrate! Try to drink about a gallon of water per day, but if your urine is not mostly clear, you'll need to increase your water ration. Boiling water usually is hot enough to have killed any microbes, but boiling water for 3 minutes is a good way to make sure the water is safe to drink. Of course, if there are any toxins or pollutants in the water, boiling will not purify them necessarily.

If you are attacked by a poisonous snake or spider, don't worry. Relax. You might suck out the poison (it is good to have a snake bite kit because the poison in your mouth may cause much harm. But you can use your mouth – or ask a buddy to do it for you). Be very sure to bind cloth above the wound very, very, very tight to reduce the spread of poison. Keep the wound lower than the heart. If swelling becomes extraordinary, some people advise bleeding or draining the wound, others do not. Use discretion and try to get medical care as quickly as possible. It is often helpful to have allergy medicine on hand: the antihistamines do wonders for these wounds.

The North Star always points in the direction of True North.



(image from http://www.survivaltopics.com/)

If you do get lost, don't regret it for one moment. It's fun to spend the night out and turn a daytrip of harvesting into a much-needed micro-vacation. Besides, with all the comforts of home in the woods, who can complain of nature's hospitality?

Yes you can eat the pines

Pine trees are one of the most easy to identify of the wild edible foods that are available all year long, no matter how deep the snow gets. Thankfully, they are also delicious if properly prepared. The needles of the pine are edible, as are the pine nuts and the sap. The pine cones are edible too. But most importantly, the inner bark is edible: this food has fed humans since our ancestors discovered the axe, and unlike the tasty nuts, no squirrel is going to beat you to your supper.

Slice the bark thin and put into a pan with olive oil, butter or the cooking oil of your choice. Fry until golden brown and enjoy fresh or store for later! Store in an airtight container, as the oil will turn rancid otherwise.

Slice the bark thin and cook dry in a pan dry roast until golden brown. The bark can then be stored, put into soup, or ground into flour, which can be used much like wheat flour.

The expert at survivaltopics.com loves the pine tree. "When harvesting pine bark expect to get very sticky, covered with pitch from head to toe; it's all part of the fun...The bark on freshly cut trees is easy to peel off. Simply cut a line through all bark layers down to the wood of the tree. Then using the edge of a tool separate the bark from the rest of the tree. Now you have a slab containing both the outer bark of the tree and the white inner bark. This is a slippery and sticky process, so be careful and have fun!...

...I very much enjoy the smell of pine pitch. It brings me back to my younger days of axe work on survey lines and timber stand improvements in the Great North Woods of northern Maine and

New Hampshire. Hard work in the outdoors is the elixir of life and the key to good health, as you must know if you live the life of an outdoorsman...

...a pine log is actually made up of a number of layers. Both the rough outer bark layer and the main woody part of the tree commonly used as lumber is non-living material. The edible part of bark is the "inner bark" or "phloem"; the actual living part of the tree. This inner bark carries nutrients from the needles and roots throughout the tree.

To harvest the living bark for food you will need a fresh tree. As soon as the tree falls or is cut down the clock is ticking; wait too many days and the bark will become very difficult to remove from the rest of the tree. However on a fresh live tree the bark is easily removed in large slippery sheets.

The first step is to remove a slab consisting of both the rough outer bark and the living inner bark from the woody trunk of the tree. Simply use a chopping tool to cut a straight line completely through all the layers of bark right down to the hard wood. Then slide the edge of a tool into the cut you made so that it is forced between the bark and wood. Work the edged tool back and forth as you pull the loosened bark with your other hand. The bark is easily removed from the wood since the space between is exceedingly slippery...I am using a tomahawk for this process but any tough narrow object such as a small crowbar or a strong stick can be used as a bark removing tool.

The larger the tree the thicker the inner and outer bark layers tend to be. At the base of this large tree the inner bark is a full quarter inch thick in places. If I were to harvest all the inner bark on the tree I would likely have well over one hundred pounds!

The most edible and tasty part of the inner bark is that which is closest to the hard woody part of the tree (or furthest away from the outer bark if you prefer to look at it that way). The portion of the inner bark closest to the wood of the tree has an almost sweet taste. The closer the inner bark is to the outer bark of the tree the stringier and resinous it becomes.

For this reason I like to slice the slab of inner bark in half and discard the less desirable piece. You may have to experiment some in order to find the thickness of inner bark that you need to remove. This varies from tree to tree and limb to limb depending upon the characteristics of each individual tree, its size, and your particular tastes.

If a tree is under a foot in diameter, more or less, there may be little inner bark that is not resinous. This comes from my particular experience; in your neck of the woods the local pines may differ due to local conditions or genetics. Just as apples from different trees can vary in taste, so too will foods from other sources...[I use] a sharp survival knife for separating the tasty portion of the inner bark from the more resinous part which is left connected to the rough outer bark.

Raw white pine bark is too fibrous to eat very much of. You can chew it until your jaw hurts and it remains balled up in one large mass. However heat the bark to crispness, something like a potato chip you purchase as a snack from the grocery store, and the bark becomes a tasty treat...I can easily eat a bag full of these crunchy bark chips as a snack, and certainly they would be a welcome addition to any wilderness survival meal. I can taste sugar and starches in this food and there are likely to be a host of valuable nutrients since it is the living part of the tree...Another good method, especially for preparing white pine bark for long term storage, is dry roasting...Once dry to a golden brown the bark can be pounded into flour that can be used as an extender for other flours, as a soup thickener etc."

Further reading

There are many schools for training, keeping and working with equines and bovines, and many experts. It often does much good to read up on the art and learn from teachers. We recommend for further reading on either bovines or equines (despite what their titles imply)

- *Bringing Up Baby* by John Lyons and Jennifer Denison
- *The Equid Ethnogram: A Practical Field Guide to Horse Behavior* by Sue McDonnell (which has applications to bovine behavior, as well).
- *Oxen, a Teamsters Guide* by Drew Conroy
- *Packing and Outfitting Field Manual* by Oliver C Hill with the University of Wyoming
- *Packin' In On Mules and Horses* by Smoke Elser and Bill Brown
- *Training Workhorses, Training Teamsters* by L.R. Miller
- *When Mules Wear Diamonds, Mountain Packing with Mules and Horses* by Stacy Gebhards
- *Working Horse Manual* by Diana Zeuner
- *Work Horse Handbook* by Lynn R. Miller
- *Working Oxen* by Martin Watts (which has an excellent history of the ox)

CHAPTER TWENTY-FOUR: OF WILD ANIMALS, GARDEN HELPERS, DOMESTICATION AND AGROECOLOGY

Reference to Chapter 23 on Work Animals

This chapter builds on the lessons of Chapter 23, on Work Animals.

Beneficial animals may be trained to become more beneficial; all animals potentially beneficial; farmer's job to provide food and shelter for all animals on their field; more biodiversity is better

Wild animals can be trained to be your auxiliary work animals! Like beneficial weeds which can be cultivated and sold for profit, the beneficial animals in your field can be brought to be more beneficial than they otherwise would naturally be. The farmer must come to understand that their job is to provide food and shelter for all the animals on their field and consider that every animal is potentially a beneficial one, whether it is a watchful hawk that eats the birds that would destroy your just-planted seeds, or the humble mosquito and fly.[345] The more biodiversity in the field, the greater the farmer's yield.

[345] We must provide food and shelter to all creatures, for in biodiversity lies the preservation of our crop. Look to the fly and mosquito for inspiration:

We've all known a friend at some time that is annoying, but who has helped us tremendously. Though some flies make themselves pests by investigating whether that sweet smell on your skin (sweat) is nutritious, or intrude in your kitchen or on your food, most flies provide necessary services to the ecosystem and your City!

Among the many good things that flies do, they pollinate as they eat the protein-rich pollen on flowers. This means that they help plants fruit and reproduce by bringing pollen (the plant's male sexual gametes) in contact with the female sexual gametes (the carpel or ovary, depending on the species). When this occurs, the flower's seeds are fertilized and more flowers grow next year when the seeds germinate in the ground.

While some insects have co-evolved with plants so that they carry great quantities of pollen on their fur, other insects - like flies - are not so helpful. While flies do have fur (many insects do), they do not lug about the same sort of quantities of pollen that bees or butterflies do.

Why not?

Flies do not depend strictly on pollen for a food source, whereas bees and butterflies do. Since it is necessary for bees and butterflies that there be more flowers next year, they do all they can - even unconsciously, by carrying pollen on their fur - to make sure that there are more flowers next year. The flowers are good friends to the bees and butterflies, making colors specially visible to their

Begin by studying their behavior

Just as the foundation of equine and bovine training begins by understanding their various instincts and needs, so too must the farmer study the instincts and needs of the animals on their field.

Study every creature on your field, consider what it needs for food and shelter and do your best to provide it and you will see, quickly, how it returns your friendship. At all costs, avoid the utilitarian relationship of *this for that*, requiring service in exchange for service, because the more you observe, the more you will understand you do not see nearly the beginning of how these creatures help you and you are most likely underestimating those services which you receive.

It is better to consider your wild animals as guests, and comprehend your role as host (providing food, shelter and comfort). They are all intelligent, conscious beings, with developed minds and emotions, and by the fact that you are more intelligent, conscious and developed, you have obligations to care for them: fulfilling your purpose in the ecology will yield more food at less cost and you will gain more by your friendship with the wild animals than you will through their domestication.

These are not domesticated creatures, per se, but are auxiliary members to the farm. They are not used in work or production, but in the ecology.

Many skills are necessary to working with wild animals, three are paramount: tracking, communication and domestication.

friends and making good landing spots for the convenience of bees and butterflies. Though plants are not especially friendly to flies, and flies are not especially friendly to plants, neither care too much. The flowers know their true friends, and the flies have other places to turn for food: if there are no more flowers and pollen to eat, they will eat something else - even the carcasses of the dead animals that would result from the lack of flowers. We begin to see that more rides on the bees and butterflies and other pollen-eaters than male gametes! Without pollination, many plants would not reproduce, and there would be much less vegetable matter and fruit for larger animals to eat!

It is important to note that not all plants reproduce by sexual means, and that many plants clone themselves through their roots, stems and other body parts. However, so many plants do reproduce sexually that if pollination were not to occur, the animals that depend on the sexual plants for food would die.

Many people are concerned about a plague destroying the bees and the loss of reproductive habitat for butterflies for this very reason. However, we must remember that there are other pollinators!

Many of these secondary pollinators - like the fly - are deemed 'undesirable,' 'noxious,' 'dangerous,' or 'pests.' The mosquito, the wasp, the ant, the fly, countless beetles and even small animals like mammals and lizards - even some larger animals, and the forces of nature - wind and rain especially - all pollinate. It is a good lesson on the importance of protecting all species - even those that are nuisances to us.

If we safeguard the secondary pollinators, even if the butterflies and bees are unhappily brought to extinction, not all the sexual plants would follow. In fact, the minor pollinators would find an abundant food source and be more active to make up for their lack of gamete-carrying capacity! Though many plants would join the bees and butterflies, many would survive to build new friendships with their now-primary pollinators

Wild animals eat crops out of a lack of better options or due to an imbalanced ecology

Learning the diets, abilities and habits of all the animals is important if the agriculturalist is to better understand how each creature affects the production of a crop. Animals eat agricultural crops out of a lack of better options presented by the agriculturalist or due to an imbalanced ecology. This will be shown through an experiment with snails.

Animals practice economy

In undertaking maintenance and other behavior, animals take into consideration the profit of the food, shelter or other resources (the nutrition gained by consumption minus the cost of obtaining that nutrition, or the calories saved through shelter minus the cost of obtaining that shelter, etc.).

There are, generally, three principal costs to obtaining food or shelter: [346]

1) The risk of predation (the risk that the animal will themselves become a meal)

2) The defenses of their meal or shelter (plant or animal, every creature that does not wish to be eaten or used as shelter attempts to impair the digestibility of their body or otherwise decrease the nutritional profit of their body, or make access to their sheltered areas difficult)

and

3) Nutritional limitations of the meal (some foods, by being deficient in some nutrients, require additional foods to be consumed)[347] or the limitations of the shelter. Many animals understand through smell or other senses how nutritious a food is before they eat it.

[346] In his essay *Economic Choice Theory and Animal Behavior*, printed in 1995 in the book, *Concepts, Theories and Rationality in the Biological Sciences, the Second Pittsburgh – Konstanz Colloquium in the Philosophy of Science, University of Pittsburgh, October 1 – 4, 1993* and edited by Gereon Wolters and James Lennox, the magnificent Dr. John Kagel, of the University of Pittsburgh's Department of Economics, demonstrates that "there was ample evidence, based on existing psychological and biological research, that animals responded to the basic hedonistic (cost – benefit) calculations underlying economic theory." Yet there was need to understand whether that behavior was consistent with more precise implications of the theory. Kagel then compares the behavior of pigeons and rats against those of people, and all three against the expected behavior calculated through economic analysis to find that all are in agreement.

[347] The editors highly recommend the reading of *North American Tree Squirrels* by Michael A. Steele and John L. Koprowski (2001), whether the reader is interested in learning about the habits of squirrels, herbivores, carnivores, or the methods required to study any animal life: *North American Tree Squirrels* rivals the works of Charles Darwin for thoroughness of method and the insight that naturally follows a focused look at a keystone species.

Farmers should increase the costs of their crops and animals and reduce the costs of wild weeds and wild animals; the farmer with reservations finds their fences, hedges and walls more effective: the relative cost for wild animals of eating wild foods will be much less than eating domestic ones

Increasing the costs of the farmer's domesticated plants and animals and reducing the costs of the wild weeds and wild animals is a good start; improving the nutritional values and ease of consuming wild weeds and wild animals is better.

To do this, freedom of entry and exit into and out of the food "market" is essential: the agroecologist must allow safe passages (refuges) through their field. This way, ALL animals can come and go, and find the best foods (which are usually not the ones people have domesticated). This must be done before the farmer undertakes "adjustments" to the prices of the food on the field, otherwise, even if a food is made more expensive, an animal may still risk obtaining it for lack of alternatives. Making fences permeable to where alternative foods are and reinforcing fences where the farmer's crops and animals are will do little good if there are no alternative foods for the animals to choose. A fox will still hunt in the chicken coops if there are no mice to eat; a deer will still eat the squashes if there is no meadow for them to enjoy.

An easy way to increase the defenses of a domesticated creature is domesticating additional plants, animals and fungi as "guardians." This is commonly undertaken: llamas are good guardians for goats and sheep and will defend their goats and sheep vigorously. Dogs, cats and snakes are often good defenders of crops. In our experience, most animals can be trained to undertake guard duty. Choose an animal equal to the typical animal predators you fear.

Guardian plants are easily established. Thorny plants, poisonous plants, big bushy plants that hide their friends... each one is suitable for some circumstances, and not for others. Like animal guardians, plant guardians must be chosen against the predator that is feared.

In your crops, plant guardians also present good hiding spots for carnivorous animals, and prey animals know this. They will avoid some plants because they fear what predator might lurk there.

Planting a nutritious and delicious hay crop away from the vegetables and fortifying the vegetable field with plant and animal guardians will reduce or eliminate predation of vegetables by most herbivores. The cost of the gift of hay will not be as great as the loss of vegetables would have been. Providing an easy to eat source of mice will protect more valuable chickens from foxes. However, this alone does not work well: those who would feed the wildlife will find much more wildlife than they can feed in a few years. The farmer must balance nature, and provide habitat for both predator and prey. When the foxes hunt the natural mice in the reservations, when the deer eat the natural grasses in the reservations, the stout fences, hedges or walls of the farmer will work better. And, the population of both predator and prey will be kept in check, with no explosions.

It is simply unnecessary to provide mice for foxes and hay for deer when reservations will do so better and at less cost!

The farmer who accepts that they will never conquer nature, that there will always be predators to their crops and animals, is more easily able to accept that they may either continue a costly attempt at exterminating their enemies, or they may work to balance their ecology

Understanding the currency of the animal economy, it is easy to set the "price" of some plants or animals higher than others: it is possible to make the lettuce crop more expensive than grass, and it is possible to raise the price of chickens greater than field mice. While it is good to become familiar with all the creatures in the field if you are to present prices specific to each species, it can be assumed every species estimates costs similarly. If one species is presenting a severe threat to the

stability of the agroecology, the human is capable of altering the price of the resources that species is over consuming or under consuming.

Fields of crops and pens of animals should be no place to rest for wild animals

Most animals will feel insecure eating the agricultural crop if they think a predator might be preparing an ambush nearby, or if they are unable to make a quick escape to shelter[348]. Fields of crops and pens of animals should be no place to rest!

Provide shelter in such a way that animals can move through the field along a path that causes the least damage and the least temptation, and do not provide shelter to wild animals near crops or pens: the best place for shelter is in the middle of the reservation because that is where you want them to stay! Provide some food for these animals near the shelter, and the most of the field will experience no or almost no predation. If you have a pest problem, do provide shelter for blinds near the problem area, but ensure that those blinds are more easily used by the larger predator than by the smaller pest-prey.

Adapting technique to the individual species that is a problem is important: while sprinkling some seed on the ground to distract the birds from digging for the buried seed, this will be largely ineffective against raccoons.

Occasionally, a stubborn individual will abnormally prefer the danger and expense of obtaining the fortified crops and animals to the easier wild ones. These may require additional fortification (such as electrified fences), chemical deterrents (chili powder works wonders), or in extraordinary circumstances, extermination.

There was once a coyote who enjoyed hunting in our fields and all but one rabbit feared the coyote. The fearless rabbit was eventually eaten at less expense, difficulty and effort than it would have required for us to hunt and shoot it or trap it – even considering the slight damage it did to our crops. A similarly fearless wild goose enjoyed our squashes for two days until it was eaten by a different coyote. Coyotes in our fields have plenty of food and do not care for our chickens.

We have been assured that squirrels will destroy our garden every year we have farmed, but it still has not happened. Once, a squirrel did strike our tomatoes. However, we were able to end the assault by providing to her a bounty of seeds (at a cost of a few cents per day) in a birdfeeder, which she appreciated more than tomatoes. We gained a valuable crop of tomatoes that year at less cost than traps, poison, bullets or other extermination would have cost. And, that squirrel so loved our seeds that she claimed it in her territory, and kept other squirrels away!

Wild pigs typically present an exception. Not because they cause a lot of damage, but because they are prized by hunters, who often will pay richly for the opportunity to kill them, sometimes

[348] Steele and Koprowski (2001) report a study by Lima, Valone and Caraco (1985), wherein grey squirrels were presented "with small pieces of cookies at varying distances from forest cover. They found that squirrels were more likely to retreat to the safety of cover when the decision to do so did not greatly reduce their rate of food intake...smaller cookies were eaten in the open more often than larger ones, and the probability of carrying any food item to cover decreased with the distance from cover...when exposed to predators, grey squirrels rejected smaller, more profitable food items (i.e., those with the highest calories per unit weight). Instead, they carried larger less profitable items to cover before consuming them because by doing so they could greatly reduce the time of exposure relative to the amount of food they retrieved."

tendering several thousand dollars to the farmer for the right to kill and keep the pig. Bears, elephants and other animals are similarly valuable and the farmer is usually justified in allowing their slaughter by human predators. However, in some circumstances, the importance of these animals to the ecology is so great that no amount of bounty offered by the hunter will compensate the farmer for the benefits to the ecology gained by retaining these unique animals. Additionally, some of these valuable animals may be trained as guard animals. Bears are easily domesticated, as are pigs and elephants.

Skunks provide some of the best guard services: animal and man fears them. A troop of skunks will prevent more damage to the field than any fence. Besides such intimidation, they also eat many damaging insects and other creatures that do not fear their extraordinarily bad smell.

Tracking

One of the most important lessons required for learning about animals is how to observe them when they aren't there. The best way to do this is through observations of how they affected their environment.

All animals affect their environment. All animals leave footprints, crush (or eat) the local flora and fauna, leave wastes and undertake all sorts of changes to their world by simply living in it.

Many books present lessons on how to identify an animal based on its footprint. But can you tell which way it was traveling? Are the footprints far apart (was it running)? Are the footprints close together (was it walking)? What other footprints are nearby?

It is a fun game that requires some logic, and one suited particularly to children – or to adults who are young at heart.

We once saw some evidence of human hunters on our land without permission. They cut our fences (what other animal could do that?) and walked with their size 10 boots to the bottom of our little creek. They left an empty bullet shell (presumably after shooting their gun). What were they shooting at? We saw some antelope tracks walking through the bottom of the little creek slowly, and evidence it had been grazing (some of the grasses had been eaten). Then, it started running fast. We surmise that the hunter was shooting at an antelope. There was no blood, so the hunter missed his target.

We needed to improve our defenses against intrusion: the hunter could have struck one of our animals by mistake, or even us!

We also recently noticed some mouse tracks across the snow. They appeared out of nowhere. Mice don't appear out of nowhere, so we surmised that there was a hole near where the tracks began (mice will cover up their holes again for warmth and protection). We saw the tracks wander here and there until the mouse found some grass to eat. It pooped and then went back home. The tracks weren't there the day before and we saw them at dawn, so the mouse must have been out for a midnight snack.

Noticing that the mouse stayed in the wild reserve, we were comfortable with our fortifications.

Try it with automobiles and bicycles, too! You can follow a car for miles, sometimes. We once owned a car that you could follow forever: it kept losing screws, nuts and important parts wherever it went!

You can use this form of observation to learn important things about your neighbors. We sometimes find nests in our field of birds and other creatures. Are they being used? We can notice

how well they're kept up, whether there are any spider webs over them, and collect other evidence to see whether they are abandoned. We can keep up on whether there is disease in the animal or plant community, understand migration patterns through our farm, understand what the animals prefer to eat and where they prefer to obtain shelter. We can better keep them off our fields.

One time we visited a friend's farm and saw two rabbit tracks wandering about. Where they met, there were a lot of tracks in every direction and some full body prints, too. The two rabbits had fought. The loser ran away, the winner chased, and then walked back home. We were able to learn that the population of rabbits was so high that they were competing for resources, and surmised (based on other evidence – or rather, lack of evidence – concerning the local coyotes, foxes, cats, and other predators) that there was not enough predation occurring to check their numbers. The answer lies in increasing the habitats for predators, or by introducing more domestic rabbit eaters to the land (such as cats, dogs or snakes). Another option to be considered is hiring a human hunter, and butchering the rabbits for game – or donating the meat to the poor for a tax credit, or for the glory of God.

Tracking is important too, if you want to find a lost animal. You can find a lost cow or horse this way, just by following their tracks.

In this game it helps to know something about the behavior of the animal. If you lose their tracks over some rocks and they leave very little other evidence, and you know where they like to live or eat or drink, you can guess their direction and maybe pick up the trail again. But if you don't know the creature well, by circling around from the point at which you lost their trail you can usually pick it up again – knowing the animal saves you lots of time, though.

Once we rented a field where a wild goose dared to eat our crops and was killed by a coyote. We saw the coyote tracks walk into some tall grass. We saw where the coyote laid down to rest until something walked by. We saw where the goose landed and walked past the grass and where the coyote sat up and ran onto the goose. We saw where the goose bit the coyote, pulling out some fur. And where the coyote ripped off the goose's neck. We saw that the coyote ate some of the goose right there, but also where the coyote carried the rest of the goose to our reservation for dinner.

Birds are very hard to track because they fly and leave little evidence. When they're on the ground or in trees, it is easier.

It sometimes helps to have an animal with good sense of smell. Pigs and dogs are excellent trackers because every animal will leave its smell wherever it goes. So long as the smell trail is fresh, the animal will be able to follow it.

Reading the ground and flora and fauna is like reading the newspaper. The facts are all written down for you, but you must use some imagination, too, if you're going to get the whole story. We used our imagination to learn the goose's terror and brave fight against the coyote, we used our imagination to "see" the rabbit fight for ourselves. We used our imagination to understand the small mouse's thoughts as it wandered here and there looking for something to eat, and the human hunter's fear of being caught trespassing while hunting to understand why he would select such a poor hunting ground as our creek: the creek is a low spot, and not easily visible from our house or the houses of our neighbors.

What would motivate someone to trespass on our land for a shot at an antelope? Hunger? Sport? What would motivate the coyote to select that piece of ground as a hunting blind? Had it seen geese walk by there?

When we saw three coyote tracks in the fresh snow, we followed them: there were no animals out to eat, what were the coyotes doing? Each led in a circle, and not one crossed the other's path. They were patrolling their territories, and our field was in the middle of three territories.

Sometimes, they patrolled within a few feet of the other's tracks, other times, they left many dozens of feet. We saw by where they turned to another direction or where they urinated and deficated that they marked their territory by trees and posts, and understood that they were patrolling primarily to assert their claim to the territory, and that they would likely be hunting later.

You learn so much by watching the animals, but you need not see them directly to learn from them. The more you know about them, the better you are able to work with them, the better you are able to protect your domestic creatures from them. Nonviolent evasion of conflict is the surest way to win against nature.

Besides such direct and practical lessons, animals present important lessons on economy, on living, on all sorts of things. Watching an insect, you'll see it spends much of its time cleaning itself. Watching how a cow selects a new patch of ground to eat, you'll learn how to quickly and efficiently organize your own labors.

Reading tracks, you'll learn how you affect your world.

Interspecies communication

Animals and plants are always talking and sharing information with each other and their world. All creatures cogitate externally, "thinking aloud," or thinking with gestures. Some chickens cluck constantly as they think, some spiders will click and hiss as they measure with their legs in the air the distance between two points (as some people count on their fingers). Some of the people who work for us sing and make poetry while they work.

It is an unconscious behavior that developed out of the necessity for coordinated action. All species need to work with each other, and the best way to do that is to share information freely. Even if information is conversed upon, simply sharing what you are feeling, thinking and observing allows others to coordinate their actions with you.

Adaptations on the part of some prey species has rendered them nearly silent, but they will still move their jaws or make other fruitless attempts at making noise as they think "aloud."

Humans are one of the few creatures that can censor their thoughts and hide what they are thinking not only from other creatures and humans, but also from themselves. This ability leads to many psychological diseases. In this sense, it is not so much an ability as a disability.

Observing animals as they communicate allows insight into how to share information back. When you hear a rodent singing as it undertakes its daily work, you can choose to sing along or not. You can learn the notes and practice them at your leisure. By associating the notes with the behavior and environment of the rodent, you might learn what the songs mean. You don't want to hear the happy harvest song in your grain bin! That means you will have to assign a cat to the bin, or else lay some traps.

It is very easy to talk with geese. Not only do they express themselves clearly with unique sound and gesture for any particular thought, but they have an aptitude to learn your human language as well. Though they may not be able to talk in your human language and you may not be perfectly able to speak goose, you can still share information.

Learning a foreign human language is important and enriching, and so is learning interspecies languages. All species share similar important words and gestures: the cry of alarm is common among almost all animals, as is the sounds and gestures of contentment, anxiety, displeasure and aggression.

While none of their languages are as complex or subtle as human language, it does not make what they have to express any less worth listening to. The farmer must educate themselves constantly, and must constantly be expressing their needs to the animals with who they work.

A nice activity to undertake is meeting your non-human neighbors. Perhaps there are squirrels, birds, or mice? Perhaps there are ants, or beavers? No matter who you live near to, it is polite to introduce yourself as a neighbor.

As courtesy, bring a welcome gift of food. Most animals like human foods, but if you take the time to learn about your neighbors, you might learn they have a favorite thing to eat. In example, most birds are omnivores, but some eat only meat or some eat only plants. Feeding a hawk safflower seeds will not be as kind of a gesture as feeding them a live mouse.

Getting to know the wild animals, their likes and dislikes, their friends and enemies, and watching the adventures they have during their days and nights as they go about their business is highly rewarding!

You'll hear and see them talk to themselves and other creatures and, if you pay close enough attention, will learn how to chat with them the next time they see you.

They'll be watching you, too. Talk with them and they'll learn how to understand. Though you may never have as in-depth of a conversation with the animal as you might with a human (for inability to communicate), the simple thoughts that you will be able to share are sometimes the most important ones.

You'll learn that their idea of friendship might be different from yours, you might disagree on many things. But this is part of getting to know another creature. You will eventually learn how to provide them food and shelter and comfort enough in their wild reserves that they do not need to come into your fields and harass your domestic creatures.

Spiders and insects are highly expressive creatures. As they go about their business, they will mutter to themselves. Some spiders will click a tune with their pincers while they work. Bees are perhaps the most expressive of the insects. They have a song for everything.

It is important to know bee talk if you're to raise bees. You can catch the buzz on what is going on in the colony without ever opening up the hive. You can listen in to the conversations the bored guards have as they wait for someone to come or go at the gate, you can listen in as they talk with the bees that are coming or going from the hive.

Put your ear up to a hive and you'll hear the hum of a thousand voices. Everyone's busy with their business and everything's fine. Hear a rhythm? Something is happening, and requires everyone's attention: maybe a swarm is being born, maybe the Queen is ill, maybe there is an enemy within. Hear silence? Open up the hive and you'll see the last few bees huddled together, mourning the death of their Queen with sad songs.

Many attempts have been made to write down "words" to describe the sounds and dances other creatures use to express themselves, but it is hard to do. Try writing your own transcripts so you can study them, and understand your new friends better.

The chief gate guard announces to all her sisters the Queen's decision that the new hive is a good place to live by raising her abdomen, standing upside down and buzzing outward. Her buzzing is of a tone and rhythm unique to this dance. It is not accompanied by any clicking of the mandibles, but is sometimes preceded by dramatic demonstrations in leg cleaning. This dance is similar to the one that is performed when a new Queen is enthroned. She is singing "long live the Queen!" or "the Queen has established her throne!" It is, in essence, a love song. "Here is home, here is where our mother lives!"

We have ants in our hives. These ants are parasitic, eating some of the honey of our bees. But they also defend our bees against mites and other predators. They do not live in the hive, and the bees tolerate them because they are helpful guests. A hive is supposed to reproduce the ideal conditions of a dead tree, with convenient spaces for building comb. In a dead tree, there are ants and many other creatures that cohabitate, helping each other. The ants tolerate the bees because of the honey, and the bees tolerate the ants because of their protection. Ants are one of the most important creatures on our fields and in our animal houses! They are our stalwart defenders. Occasionally, we see the guards of our bee hives talk to the ants, and the ants talk to the bees: they exchange greetings, and recognize each other as adopted family by exchanging smells and particular touches with their antennae.

The response to the dance is echoed by the other gate guards by a line dance that echoes the fanfare of the chief guard. Second in importance only to the Queen herself, the chief guard (which may be any of the senior-most individual guards who is on duty) has the important job of relating important information between the inside and outside of the hive. The chief guard will share information with outgoing foragers from those who just returned about where good pasture is. She will also communicate with the outer guards to learn whether there are any enemies approaching the hive. She can marshal the bees from within the hive to swarm in attack against an enemy or in escort for a new Queen. She even directs those foragers entering the hive to where they need to go within the hive. She is aided by other gate guards, who help her tiny voice be heard by echoing her dances and songs. The song itself is chorused for the whole night long – the hive will buzz with excitement as they discover every reach of their new hive, and plan out their Queendom. The Queen settles in the best part of the hive and begins to lay eggs as her daughters and sisters get food, build comb, and undertake the other necessary business of living.

Politeness is key in the animal world, and the protocol of greeting is what defines the relationship of friend or enemy. Often, two would-be enemies will greet each other civilly before they attack. The response of two friends meeting is also profound.

As you watch the wild animals like Enos Mills, you will notice, as he did, that they are watching you. They are trying to learn your language, too! Once we had neighbors who only spoke Spanish. Their wild animals learned all kinds of Spanish phrases, but did not understand our English.

Domesticating wild animals for profit

Though snails are referenced here, the lesson is easily applied to any number of wild creatures.

Snails are enemies of some gardens, but are welcome guests in ours. They eat weeds! But if you want to develop this helpful relationship further, you can domesticate snails – as you can domesticate many other wild creatures. Domestication does not begin and end with a reliance on humans for food and shelter, but begins when the animals or plants are given a home (a domus) which they must undertake effort to keep. It is a relationship wherein the human and the creature benefits equally, whether that creature is a plant, animal, fungi or microorganism.

Snails are sometimes used to improve soil quality, in a similar way to sheep: as they slime and manure the soil, the soil is fertilized. Usually, however, they are kept in pens and fed scraps from the field, or a specialized diet for the same reasons that sheep are penned from the field.

Snails can be raised for human consumption. They also can be used for animal feed, especially for birds, dogs and other carnivores. First we will give some background on the snail itself, since part of the purpose of this chapter is to introduce to you the garden helpers, and this is a very helpful garden resident, useful in the field, in ponds, in sea water, and even in greenhouses.

This garden friend is different from others presented in this chapter, in that it is presented in a way that demonstrates its capacity for domestication. Every creature can be domesticated. Foxes can be raised for their pelts or as guards, even the squirrel can be domesticated to protect fruit trees if it is trained to appreciate seeds instead of fruit, and encouraged to defend its territory.

Taming animals so they do not harm your crops is not domestication. Domestication requires the provision of food and shelter.

Snails – Domesticated and Tamed I

Snails are an example that clearly demonstrates the difference between taming and domesticating creatures. We will illustrate how wild snails behave, and how the processes of domestication is defined by these rules of snail nature to show the subtle differences between domestic snails and wild snails: they receive food and shelter designed for them.

Snails – Domesticated and Tamed II: Domesticating snails, the enclosure

Snails are highly intelligent and strong creatures that require sophisticated pens to contain them. While walls are ineffective, moats are not. Screens may be used in combination with walls if the screens are securely attached (snails are much stronger than you'd think).

Some snail farmers resort to electrified fences (with wires less than an inch apart), but this is unnecessary and almost silly, considering that a screen would do better for much less cost: besides, an electric fence will not keep out predators. While it is reported that snails hate copper and will not pass a copper barrier, this has not been true in any of our trials.

Walls should be high enough to accommodate shelter plants and the walls should be narrow enough so that a person can comfortably reach to the middle (enclosures should not be more than about 4 feet wide).

In winter, the snails can be enclosed in a greenhouse, left to hibernate or breeding stock can be relocated indoors. Greenhouse snails worry nothing about winter.

The area of an enclosure can be rotated like pasture. Where the snails were living last will be very rich soil the next year.

The Food and Agriculture Organization of the United Nations in their *Better Farming Series, Farming Snails 1 and 2* recommends a 3 pasture rotation, where a garden is planted for snails and then snails are moved onto the garden and graze upon it, and then a garden for people food is grown.

Snails need damp, not wet, environments. Although snails need moisture, you must drain wet or waterlogged soil to make it suitable for them. Similarly, rainwater must run off promptly. Snails breathe air and may drown in overly wet surroundings. A soil moisture content of 80% of capacity is favorable. In the hours of darkness, air humidity over 80% will promote good snail activity and growth.

However, we have had success with as little as 30% moisture content and less than 10% humidity.

If they are raised outdoors, irrigate them as you would leafy vegetables. Taking a sponge or rag in hand with some water and sprinkling their favorite shelter plants will also do well. Even if the snails are not moistened, they will seek out the moisture at night – so it is best to sprinkle in the evening and at night.

The UNFAO makes it clear: "if green leafy vegetables grow well in your soil, snails will also grow well."

The UNFAO recommends shelter plants for snails to be centrally located for the convenience of the snails. This is true, too, for wild animals. Putting shelters for them in central locations allows them to better access your field. Putting shelters for carnivorous protectors far off to one corner of a field does not do much for the far corner unless the field is very small. Putting the shelter plants for snails in a corner does not let them graze well.

These shelter plants can be tasty things for people that the snails do not like to eat. For example, asparagus is an excellent high value crop that snails do not eat but do enjoy for shelter and that people eat and enjoy.

Snails – Domesticated and Tamed III: Snail biology and specialized production

A snail breaks up its food using the radula, which is a chitinous structure containing microscopic hooks called cuticulae. With this the snail scrapes at food, which is then transferred to the digestive tract. This is why, in a quiet setting, a snail can be heard 'crunching' its food: the radula is tearing away at what it is eating. The food is digested in the shell, and waste material exits near to the air intake under the shell.

The cerebral ganglia of the snail form a primitive brain divided into four sections. This structure is very much simpler than the brains of mammals, reptiles and birds, but similar to the other mollusks.

Most snail activity, including feeding, occurs in the cool, dark nighttime, with peak activity taking place 2 to 3 hours after darkness begins. However, some snails are more active in the daytime. The cooler temperature stimulates activity, and the nighttime dew helps the snail move easily. They hide in sheltered places during most of the day. If necessary, use misting sprayers in dry climates to maintain adequate humidity and moisture levels. A simple sprinkler will also do, or a watering can. Greenhouses are easily kept at the correct moisture.

As the snail grows, so does its calcium carbonate shell. These shells can be very colorful in some species, and may be sold as ornaments or jewelry. The shell grows additively, by the addition of new calcium carbonate, which is secreted by glands located in the snail's mantle. The new material is added to the edge of the shell aperture (the opening of the shell). Therefore the center of the shell's spiral was made when the snail was younger, and the outer part when the snail was older. When the snail reaches full adult size, it may build a thickened lip around the shell aperture. At this point the snail stops growing, and begins reproducing, and is ready to harvest for meat.

Some snails hibernate during the winter (typically October through April in the Northern Hemisphere). They may also estivate in the summer in drought conditions. If snails are not able to hibernate due to things like global warming, the snail can die or its species may even go extinct like the Aldabra banded snail. To stay moist during hibernation, a snail seals its shell opening with a dry layer of mucus called an epiphragm. Not all snails need to hibernate, though.

Some freshwater snails such as apple snails have gills and a "door" or operculum to close the shell when they withdraw. This structure functions as protection from predators as well as protecting the soft tissues from desiccation when an aquatic habitat dries out temporarily.

There are many breeds of snails. Some are very large (as big as a child's hand, or bigger), some are very small. Each buyer has a preferred breed, but the farmer who would raise them simply as an animal feed supplement should choose the kind most suited to their environment.

Some water snails produce profound toxins which may be used in medicine, and water snails produce the most beautiful shells. If raising snails for shells, raising a variety of species would be best so that buyers may choose their favorites for jewelery!

Prialt, an experimental painkilling drug, according to the website prialt.com, "is indicated for the management of severe chronic pain in patients for whom intrathecal (IT) therapy is warranted, and who are intolerant of or refractory to other treatment, such as systemic analgesics, adjunctive therapies or IT morphine. PRIALT is not a narcotic and is non-habit forming. PRIALT has a proven safety profile administered in over 1254 patients. PRIALT is effective for neuropathic pain management. Neuropathic pain is categorized as pain originating from a damaged nervous system and which is only partially opioid responsive. PRIALT is indicated for the IT treatment and management of severe chronic pain for patients who are intolerant of other treatment options such as analgesics or IT morphine." It is snail venom, from the carnivorous and predatory cone snail. The cone snail uses a poison "harpoon" in hunting its prey. This is where the poison – and medicine – comes from. Prialt is currently being looked at as a treatment for Alzheimer's disease, Parkinson's disease, and epilepsy.

Though Prialt may cause, as a side effect, "severe psychiatric symptoms and neurological impairment," the safe use of snail mucous in cosmetics has been undertaken since civilization began. Snail mucous has been indicated to promote the stimulation of new collagen and elastin fibers, and increased production of fibronectin proteins. It is moisturizing and antibiotic. It keeps snails moist and wrinkle free, and can do the same for people. In modern times, beauty blogs are abuzz with success stories from people who enjoyed the benefits of snail mucous. Have the snails crawl on glass plates and collect the mucous from the plates: one way to ensure all the snails are milked at the same time is to put a glass plate between the snails and their food. Simply collecting it from their enclosure encourages the collection of feces as well as mucous. Sometimes, mucous may be collected by encouraging the snails to hibernate, and then collecting the mucous seal that the snails produce to keep themselves hydrated during their sleep.

Snails are also good companion animals in aquacultural production, keeping an aquarium or pond clean.

All land snails are hermaphrodites, producing both spermatozoa and ova. Some water snails have separate sexes (they are male or female). The age of sexual maturity is variable depending on species of snail.

Prior to reproduction, most land snails perform a ritual courtship before mating. This may last anywhere between two and twelve hours. Prolific breeders, pulmonate land snails inseminate each other in pairs to internally fertilize their ova. Each brood may consist of up to 100 eggs, but sometimes are as few as less than 10.

Snails are highly social creatures and will "hug," "kiss," and play together. Large snails willingly give rides to small snails, and snails will, when safe, secure and comfortable, sleep out of their shells so they can touch their friends as they sleep. They do not readily bond, but are very friendly. Snails do better in the company of other snails than when alone: when alone, they are distressed and do not eat as much.

Land snails bury their eggs in shallow topsoil primarily while the weather is warm and damp, digging with their foot. Egg sizes differ between species. They are small and white, often about the size of this "O." After 2 to 4 weeks of favorable weather, these eggs hatch and the young emerge. Snails may lay eggs as often as once a month.

The snail's shell develops while it is still an embryo; it is, however, very weak, and needs an immediate supply of calcium. Newly hatched snails obtain this by eating the egg from which they hatched. The cannibalization by baby snails of other eggs, even unhatched ones, has been recorded. Promptly after they are finished ingesting their egg casings, they crawl upwards through the small tunnel in order to digest the egg. At this stage, the young are almost completely transparent and colorless. Their shell is usually slightly smaller than the egg they hatched from, but their length when out of their shell is slightly greater than the egg diameter. After a few weeks, the snails will begin to show their first tinge of color before they turn their adult color. Roughly three months after they have hatched, they will look like miniature versions of their mature kin. They will continue to grow, usually for two to three years, until they reach adult size. Irrespective of their rate of growth, however, it will still take at least 1 year before they are sexually mature.

There have been hybridizations of snails; although these do not occur commonly in the wild, in captivity they can be coaxed into doing so.

Parthenogenesis (self-fertilizing) has also been noted in certain species.

Freshwater pond snails do not lay their eggs in the ground, but instead they attach them to something solid, or in some genera they carry the eggs internally until they hatch, a form of vivipary.

The lifespan of snails varies from species to species. In the wild, Achatinidae snails live around 5 to 7 years and Helix snails live about 2 to 3 years. Aquatic Apple Snails live only a year or so. Most deaths are due to predators or parasites. In captivity, their lifespan is much longer, ranging from 10 to 15 years for most species. On occasions, snails have lived beyond this lifespan, up to 30 years.

While snails are regarded as slow, we have recorded snails sustaining speeds of an inch every second, or .05 miles per hour.

Snails – Domesticated and Tamed IV: Domesticating snails, feeding snails and sheltering them

Each species of snail prefers different shelters and different foods. Experimentation will demonstrate their preferences, but the UNFAO recommends rape (and other cabbages), amaranth and papaya leaves are good food, horse radishes, beets, bananas, loofahs and burdock are good for both food and shelter, and asparagus and plantago are great shelter plants.

By these recommendations, it is easy to see that snails can be paired with shelter plants that are valuable for human consumption (such as asparagus): they will not eat the asparagus, but will fertilize the plants and improve production. Our experiment with snails demonstrates, too, that preferences can be shaped by the farmer.

It is important to remember that snails eat many things, and can be trained to eat almost any plant material.

Some snail farmers feed their animals grain to fatten them up. This is unnecessary, as plant scraps can be fed to them at less expense with similar results. A vegetable diet will improve the flavor of the snails, as well. Some buyers demand grain finished snails, though, so consult with your buyer before making decisions on feed.

Snails require plants to obtain shelter on. They will not typically eat the plants they obtain shelter from, and eat their shelter plants only out of necessity when no other choice is found.

The UNFAO says that "snails need plants for both food and shelter. Most kinds of snails use several kinds for food and several other kinds for shelter. They may also use different plants of for food and shelter at different times of the year. Sometimes during the growing season, snails eat and find shelter on the same plants...so, before you begin you will have to find out exactly what plants they like to eat. To do this you will have to watch snails at night when they eat...you will also have to find out what plants they like for shelter. To do this you will have to watch snails during the day when they rest."

One of the largest snail farms, Helix, of Portugal, does not provide shelter plants, but provides sheltered greenhouses, which suffice. On their website (http://www.helix.web.pt), they proudly explain their operations: the snails are started in nurseries (which are supplied by reproduction facilities), moved to fattening parks and finished:

Each stove has about 500 m^2 and possess a structure of galvanized tubes. They are covered by an 80% shadow-net temperature control and by a thermal plastic over the reproduction area. These nurseries contain an irrigation system by sprinkling, controlled by a hygrometer/programmer, that keeps the humidity between 75% and 90% permanently

Each fattening parks enclose an area of 1.2 for 10 meters. They are are equipped with an anti-escapes net and include two food plates for m^2 with appropriate ration and about 800 broods. In this area, there's an irrigation system with sprinklings.

In this Reproduction area, there are several boxes, with a geotextile tissue in the base for the humidity control. Each one of these boxes contains ration and four vases with land for the spawning. In each one of them, we introduce 100 reproducers in the month of March of each year, when initiates the reproduction period begins, about 16 the 20 weeks.

From June the first adults appear and then the recovery process starts. They are accommodated in net-bags, in portions of 5 kg, and are placed in cold chamber or ventilation to dry, for posterior exportation. This operation continues until November.

The period between December and February are hibernation months: the future reproducers and the snails that had not reached the adult size hibernate.

Helix relied on French agricultural specialists to design their facility: "As a french traditional tidbit, it's there that the knowledge for its creation is acquired and it's also there that the market is promising. So, it was under French technicians instructions that appeared the company Helix, in 1991, that produces about two tons of snails per year. This site presents you our method to its creation, giving you the possibility of nowing [sic] a delicious dish – 'escargots', very appreciated in France."

Snails – Domesticated and Tamed V: Kinds and uses of snails

Helix raises three species of snails, *Helix Aspersa Muller* ("Petit Gris"), *Helix Aspersa Maxima* ("Gros Gris") and *Helix Pomatia* ("Bourgogne").

The UNFAO warns that while "there are many kinds of land snails that are good to eat some kinds of land snails are not good to eat and they may even make you very, very sick." The UNFAO recommends raising:

Helix pomatia : Pomatia is found in places where there is winter and summer, weighs 15 to 25 grams, measures 40 to 50 millimeters, a strong shell that is pale brown and off-white, matures in 2 to 3 years and lays 30 to 50 eggs per growing season. The snail farm, Helix, reports that their Pomatias are native to France and are smaller (28 to 35 mm).

Helix aspersa : Aspersa is found where there is winter and summer, weighs 4 to 20 grams, measures 30 to 45 millimeters, has a weak shell with broken light brown and black stripes, matures in 1 year and lays 40 to 170 eggs 1 to 3 times per growing season. The snail farm, Helix, reports that their Aspersa Maxima is 40 to 45 millimeters, and their Aspersa Muller is 28 to 35 millimeters, and are native to North Africa and Mediterranean areas, respectively.

Achatina achatina : Achantina is found in tropical places where there is no winter, weighs 150 to 200 grams (or more), measures 90 to 130 millimeters, has a strong brown shell, matures in 2 years and lays 100 to 300 eggs once or twice per season.

Archachatina marginata : Archachatina is found in tropical places where there is no winter, weighs 150 to 200 grams (or more), measures 90 to 130 millimeters, has a strong, brown shell, matures in 2 years, and lays 5 to 10 eggs each season.

Helix exports its 2 tons of snails to France, but is trying to develop markets in Portugal as well. "The snail is constituent part of the French alimentary string, being consumed as entry or even as main dish. In the Christmas and New Year parties, the french 'escargots' go always to table, and this is the period of bigger consumption. It is traditionally cooked as a sophisticated entry dish, with a sauce of butter, garlic and parsley. In Portugal, the consumption of the snail is still for exploring and is generally as a tidbit that it goes to the table."

Though the French intensive method is effective, the snail needs shelter for sleeping, resting, protection from the elements, and when not screened in, protection from predators. This shelter is best provided by farmers not wishing to invest in the elaborate equipment with which Helix is endowed by providing plants in the pen.

Snails – Domesticated and Tamed VI: Marketing snails

Shipping snails for sale in animal feed or for human consumption requires harvesting them first. First, select the biggest, healthiest, most beautiful, most desirable snails. Set them aside for breeding stock. Then select active, healthy ones: do not ship sick snails, it is dangerous to the consumer and bad customer service. You will lose business worth more than the earnings you'd make on that one sick snail.

The nutritional content of the snails will vary somewhat during the year, but not in any significant way. Some human consumers will claim that the flavor is different at different times of the year.

Feed the selected snails cornmeal or bran in a container without dirt for 3-4 days to help clear out their digestive system. Clean the snails and their container at least once, preferably three times per day. Then, do not feed the snails prior to shipping, if you ship them alive. This will prevent the shipping container from being soiled by manure.

Induce hibernation by removing access to water. The snails can then be packed into a shipping container. Be careful not to damage the snails as you pack them, and to pack them carefully. Secure the lid of the shipping container, just in case the snails wake up and try to escape (remember they are very strong and smart).

Some farmers will kill and can the snails on farm, but shipping live snails is better as it preserves the most nutrition for the animal or human who will eat it.

The way to prepare snails (dead) for sale is simple and best described by the UNFAO. First the snails are starved so their intestines are clean. Then they are washed. Then they are drowned in cool water with salt and vinegar. When the water turns white, the snails are being washed. Water is changed and more salt and vinegar is added until the water no longer turns white. Then the snails are boiled with salt and vinegar for at least 5 minutes. The snails are ready to be cooked...

We have successfully entertained snails in our gardens without any damage to our crops. They prefer, after all, our crops as shelter plants and eat the weeds. We had one species of snail, the Rocky Mountain Capshell Snail (which is a threatened species here) enjoying our fields, even while facing extinction in the wild.

Snail Nutritional Value for Animal Feed or Human Consumption

The USDA has tested raw snail meat for its nutritional content. We reproduce what the USDA reports here:

Nutrient	Units	Value per 100 grams
Water	g	79.2
Energy	kcal	90
Energy	kJ	377
Protein	g	16.1
Total lipid (fat)	g	1.4
Ash	g	1.3
difference	g	2
Fiber, total dietary	g	0
Sugars, total	g	0
Calcium, Ca	mg	10
Iron, Fe	mg	3.5
Magnesium, Mg	mg	250
Phosphorus, P	mg	272
Potassium, K	mg	382
Sodium, Na	mg	70
Zinc, Zn	mg	1
Copper, Cu	mg	0.4
Selenium, Se	mcg	27.4
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.01

Nutrient	Units	Value per 100 grams
Riboflavin	mg	0.12
Niacin	mg	1.4
Vitamin B-6	mg	0.13
Folate, total	mcg	6
Folic acid	mcg	0
Folate, food	mcg	6
Folate, DFE	mcg_DFE	6
Choline, total	mg	65
Vitamin B-12	mcg	0.5
Vitamin A, RAE	mcg_RAE	30
Retinol	mcg	30
Carotene, beta	mcg	0
Carotene, alpha	mcg	0
Vitamin A, IU	IU	100
Vitamin E	mg	5
Vitamin D	IU	0
Vitamin K	mcg	0.1
saturated	g	0.361
Fatty acids, total monounsaturated	g	0.259
Fatty acids, total polyunsaturated	g	0.252
Cholesterol	mg	50

The high protein content in the snails (16.1%) combined with the micronutrients make it an attractive animal feed to those omnivores that would be benefited by protein supplementation (such as chickens and fish).

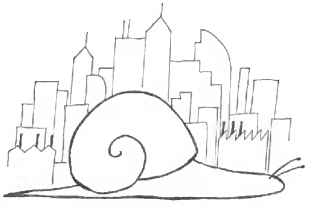
They provide a very balanced protein, and their shells (not included in this analysis) are an excellent source of calcium – very important to egglaying birds.

Snails – Domesticated and Tamed VII: Snails in the garden

Cultivated snails also produce high quality soil amendments (especially when their shells are ground up into the snail compost). Do not underestimate the value of rotating a herd of grazing snails through the garden!

Besides the infinite amusement of watching these busy mollusks, snails are valuable to the farmer who enjoys them eating the garden's weeds.

Those who would raise snails should be careful to protect them against chemical toxins. We have them as one of our farm's logos, or emblems (below) because the sign of a healthy farm is the presence of such sensitive mollusks as snails.



Garden Helpers

Snails can be domesticated and their value to the farmer increased. However, even without domestication, wild animals can be garden helpers and will provide services and products to the farmer.

Every life form is motivated to increase its numbers and strength[349] and there are many ways to enter into partnerships with other life forms that secure both the human and the partner's interests in increasing numbers and strength. We will provide several examples of how some of the common wild animals serve the farmer, but caution that there are often more services which go unaccounted for than we can describe or most farmers will ever notice.

[349] An excellent example can be found in squirrel nesting behavior: even squirrels that were born of different mothers will nest together and share resources during dangerous times. Though each squirrel competes with other squirrels to pass on its genes, it is in the interests of all squirrels that *some* squirrels survive. This was observed by William D. Hamilton in 1964, and is reviewed in *North American Tree Squirrels* by Michael A. Steele and John L. Koprowski (2001): "William D. Hamilton postulated the revolutionary idea of inclusive fitness to explain why social insects such as honeybees and ants obtain individual benefits even by forgoing reproduction and serving as workers. His *Genetical Evolution of Social Behavior* suggested that an individual's success at passing on genes to the next generation (an individual's inclusive fitness) was composed of two components: direct fitness, where genes are passed on through one's direct descendants, and indirect fitness, where one's genes could also be passed along by assisting indirect descendant relatives or collateral kin" In terms of domestication, the alliance becomes so strong between two species that they become like kin, and just as ants will improve their herds of aphids and preserve their breeding stock in disasters, just as people will go through extraordinary lengths to save their animals, when two species enter into the domestic partnership, they understand that their mutual interests for survival lie bound together.

Foxes

When we learned that foxes had been seen around the farm, we were very pleased. The fox is a very beneficial creature to have in a garden, and is often underappreciated. More can be said in regards to this wonderful animal than would fit in this entire book, and we recommend further reading and observation on the subject.

There are several species of fox that live in North America, but the most widely distributed, and the most well known, is the red fox (Vulpes vulpes). This fox is usually red in color, with black legs and a white tip on its tail, although it can also be black or a mix of red and black. The fox is a member of the Canid family, and is related to other canines both wild and domestic. It is smaller than other wild canines, and much more finely built.

As with all canines, the fox is a hunter and a scavenger. It primarily eats meat, whether it catches the animal itself or finds it already dead. It hunts small mammals, birds, and insects, and rarely hunts anything bigger than a rabbit. Analysis of fox stomachs and behavior demonstrates that the primary component of its diet is usually insects such as grasshoppers, and small mammals such as mice and voles. It also frequently hunts squirrels, birds, rabbits, and other such animals, but is less successful at catching these. Foxes have also been reported to eat seasonally available fruits and berries, although these do not provide a large portion of the fox's diet in any season.

When food is abundant, a fox will catch more than it can eat that day and hide it. This behavior is called "caching" (pronounced "cashing"). Although many animals cache their food, the fox's method is very interesting and different from other animals. It first carries its food away from where it was killed or found, and selects a place to bury it. Then, without setting it down, the fox digs a hole just large enough to hold the food and deep enough so that when the food is places inside it will be about three inches deep. Then the fox places the food inside and buries it, patting down the topsoil so that no trace can be found of the soil having been disturbed. The fox finishes it off by rearranging the leaves and other organic matter that were on the ground over the hole. The fox always digs a new hole for a new foodstuff, and scatters these caches throughout its territory. The fox is able to remember where its holes are to within a few feet, and smell them out to the precise spot when it wants to eat what it hid there.

Foxes are a welcome member to the garden habitat, as they help control the populations of smaller creatures that eat the plants. During the summer, when the garden's populations of plant-eating creatures swells, the fox is hungry: fox mothers and father foxes need to catch extra prey to feed their kits. And, as they try to catch more than they can eat in order to save some for later, they keep their prey's populations down even more. Even when the fox has an unsuccessful hunt in the garden, it will scare its prey into hiding, and possibly even discourage that specific prey animal from entering the garden at least for a little while.

Further Reading:

Red Fox: The Catlike Canine. J. David Henry, 1986. An excellent book on red foxes, based on the author's many years living among them and studying them in their natural habitat.

Dragonflies and Damselflies

All dragonflies belong to the taxonomical order Odonata (oh-den-ah-tah), which is Greek for "toothy ones." Don't let their name or large size scare you though! They cannot sting, and will only bite if you roughly catch them with your bare hands.

Damselflies are closely related to dragonflies, as they also belong to this order. Dragonflies and damselflies are as similar to each other as butterflies are to moths. The main differences in appearance between dragonflies and damselflies are in their body shape, eyes, and wings.

Dragonflies have huge eyes that usually sit very close together, and usually hold their wings flat and to the side (like an open book) when at rest. Damselflies are smaller and have very slender bodies, their eyes are often more separated than those of dragonflies. They usually hold their wings folded together above their bodies when at rest.

Dragonflies can be classified within various families, seven of which live in North America. They are usually identifiable based on their body shape. For example, Darners have a body shaped like a knitting needle (hence the name), long, straight and pointed at the tip, whereas Clubtails have a bulge at the tip of the tail. Dragonflies in all families come in many colors such as blue, red, and green, and can have patterns on both their wings and bodies such as stripes and spots.

Dragonflies are carnivores and eat bugs, both as "baby" dragonflies and as adults. They lay eggs in water, and the larvae eat the adults and larvae of other insects, such as mosquito larvae. The adults eat a variety of insects, including those that are often considered "pests". Some species prefer larger bugs, and will even eat other dragonflies, while some prefer very small bugs. Those that eat larger bugs bite off the head of their prey to kill it.

They are adept at avoiding being caught due to their unique wing structure which allows them amazing maneuverability, but are still often eaten by various birds and spiders. The eggs and larvae also are sometimes eaten by water dwelling carnivores such as fish and other insect larvae. Thus dragonflies play a part in the food chain of the garden and surrounding ecosystem.

Dragonflies are most often found near water, as they lay their eggs in the water. Sometimes they can also be seen farther from water, though, as some species go "inland" during their immature adult stage. Whether near the water or not, they can often be seen perching on a stick, plant, or rock and farmers who want these useful insects in their fields should provide perches from which the dragonfly may observe its surrounding territory.

The perching dragonfly may be basking in the sun to stay warm, watching for prey, or else it may be a male watching for any females to fly by. They can also be seen flying low over plants and water in search of a meal or a mate. The males of some species are territorial, and can sometimes be seen chasing off other males from "their" territory.

If you are interested in learning more about these fascinating insects or need a good identification guide for local species, check out the recommended reading, then study them first hand.

Further Reading:

1. *Dragonflies through Binoculars: A Field Guide to the Dragonflies of Western North America*. Sidney W. Dunkle, 2000.

2. *Dragonflies*. C. Berger, 2004.

3. *Dragonflies of the World*. Jill Silsby, 2001.

Butterflies, Skippers and Moths

These three types of insects belong to the taxonomical order of Lepidoptera (leh-peh-dahp-te-rah). Lepidoptera is Greek for "scale wing."

Sometimes they can be very hard to distinguish from one another! Moths can be very colorful like most butterflies, and butterflies can be plainly colored like many moths. Skippers often look a bit like both butterfly and moth at once. Moths, skippers and butterflies come in a variety of sizes, also.

So how do you know which is which? Although there are exceptions, some generalizations can be used. Butterflies tend to be active in the daytime, their antennae have a swollen tip, and they hold their wings vertically over their bodies when at rest. Skippers are more similar to butterflies than to moths, with the main difference being that their antennae end in a hook. Moths tend to be nocturnal, their antennae can have a variety of tips but are not swollen or hooked, and their hold their wings flat (like an open book) when at rest.

Despite these differences, all of the hundreds of species of Lepidoptera that live in Colorado fill the same ecological niche, and help the garden in the same ways.

Some butterfly species rely on one or two species of plants when they are young caterpillars. Without these specific plants, the butterflies would go extinct. Many of these essential plants are "weeds."

The most widely acknowledged garden help that Lepidoptera provide is pollination. Most flowers require this cross-pollination in order to reproduce and Lepidoptera helps bring pollen from flower to flower: when an adult butterfly dines on a flower's nectar, some of the pollen sticks to its proboscis (tube-like mouth). Some of this pollen is left behind and more is picked up at every following flower it drinks from. This allows the plants to sexually reproduce.

There is also another less well known ways that Lepidoptera helps the garden. Lepidoptera begins life as a caterpillar. But even before these caterpillars grow up to be helpful pollinators, they help gardeners by eating weeds and harmful insects! Some caterpillars, such as the Harvester (Feniseca tarquinius), are carnivorous: they eat some of the bugs that might otherwise have damaged the plants.

While some caterpillars eat domestic plants, farmers should tolerate these caterpillars if they want these important pollinators later. If there is a significant problem, try maintaining a reservation of weeds every 5th bed and aisle (as described previously), or planting a flowering, fruiting crop to take advantage of the future moths and butterflies.

What happens to the butterflies in winter? Although some butterflies, such as the famous Monarch, migrate to warmer climates during the winter months, most Lepidoptera actually live in your garden all winter. These Lepidoptera survive the cold temperatures and lack of food by hibernating, either as eggs, caterpillars or pupa. (The pupa of a moth is a cocoon; the pupa of a butterfly is a chrysalis.)

Some species mate in the fall and then lay their eggs in a protected location, such as under the soil or in a pile of leaves, where the eggs will lie dormant until the warm temperatures of spring initiate their growth and development. This is why it is important to leave vegetation standing all winter and only till in the aisles – and to maintain reserves for the animals.

Other Lepidoptera lay their eggs in the summer and early fall, so that the eggs develop and hatch into caterpillars before the winter comes. These Lepidoptera spend their winter as

caterpillars, usually hiding underground in a hibernation state. When the spring comes, they "wake up" and continue their growth.

The Lepidoptera that spend the winter as a pupa prepare for winter by "bundling up" in a pupa in a protected place, and hibernating inside. When spring comes they emerge as a butterfly. These types of Lepidoptera are often the first butterflies you will see in the spring, as they are the closest to their adult form when they begin their winter hibernation.

Some species are domesticated for silk production. Silkworms are actually caterpillars, and the cocoon is made of silk! Silkworms enjoy mulberry leaves, and these are fed to the caterpillars in large coop-like buildings where the caterpillars are penned on shelves (similar to how snails are penned).

Nobody yet knows all the ways that Lepidoptera helps the garden: Lepidoptera are part of the food chain, and other insects, birds, small mammals, reptiles and amphibians rely on Lepidoptera as much as human gardeners. Without Lepidoptera, many animals and people would not eat or live nearly so well!

Further Reading:

1. *Butterflies through Binoculars: A Field Guide to the Butterflies of Western North America*. Jeffrey Glassberg, 2001.

2. *Butterflies in the Backyard*. Scott Shalaway, 2004.

3. *Silkworms*. Sylvia A. Johnson, 1982.

Beetles

There are over 250,000 species of beetles around the world, and new species are still being discovered. All beetles belong to the scientific order Coleoptera (ko-lee-ahp-tuh-ruh). Within this order, they are divided into over 150 families. With such wide diversity among beetles, there is much that can be said about them and their places in the garden.

Although there are huge differences in appearances between the different species of beetles, they do have some similarities that distinguish them as beetles (and not, for example, butterflies or dragonflies). The main difference is also the name of their order: Coleoptera is from the Greek for "sheath wing." All beetles have two pairs of wings: their front wings are hard, and commonly but incorrectly called "shells;" their hind wings when not in use are hidden under the hard front wings, and often look shiny and fragile. The front wings, or elytra (eh-lie-truh), are used for creating lift and balance during flight, much like an airplane's wings. The hind wings are used like most other flying insects' wings: they are flapped rapidly and provide the main power for flight.

Beetles, like all animals, have territories and love to explore and increase their range of influence. Beetles are well adapted to their environment, often enjoying benefits of a camouflage that helps them blend into the places they like best.

All beetles start life as eggs. When they hatch, they are then called larvae or grubs, although each beetle species often has another name for this stage. For example, the Southern Corn Rootworm beetle's grubs are called worms: they are not true worms, but they are worm-like in appearance. Grubs of different species eat different things. Some eat decayed plant and animal matter, some eat live plants, some hunt other insects.

Like their young counterparts, adult beetles also feed on a variety of things. Some beetles are herbivores and eat plants. Some are carnivores and hunt other insects, snails, worms, and sometimes

even small fish. Some are scavengers and eat live and dead plants and animals whenever they can find any.

As the diets of different species vary greatly, so do their roles as helpers in the garden. When the grubs and adults of certain species feed on insects, other larvae, and snails, they are helping to control the other populations. For example, ladybugs feed on aphids, which might damage the plants they live on if their population got too large.

The larvae and adults that feed on decaying matter and other scavenged food help by keeping the levels of dead materials low. This can help keep the levels of fungus and molds lower, which could potentially damage the live plants.

The beetles that feed on live plants also help the garden. Some of them feed on pollen, and so they help by pollinating the plants.

Others feed on the leaves, stems, and roots of the plants. These beetles are those most often thought of as pests. However, many of them also eat the plants that are generally considered weeds. Even if they don't eat the weeds, they rarely become problems in our fields because provide the important role of becoming the meal of predator insects and other animals!

Bees, moths, butterflies, wasps and mosquitoes are not the only creatures that pollinate! Some beetles eat pollen and will fertilize your flowers so that you can enjoy tasty fruit in the summer or autumn. While every species is important and the growing fears of an extinction of bees is valid, life is highly resilient because many different species will fill the same ecological niche. Biodiversity is important: if one species fails and becomes extinct, with biodiversity, there is another species that may make the attempt and succeed.

Beetles are only truly damaging to crops when their populations get out of proportion for the local ecosystem. By encouraging all insects and other animals to live in your garden, even these "pests" won't do any serious damage.

Recommended further reading:

Beetles. Sylvia A. Johnson, 1982. A good children's book that focuses on scarab beetles but has good general information as well.

Ants

Ants are an underappreciated group of animals, and often unnoticed despite their large populations. Ants exist everywhere in the world, except in perpetually frozen places such as the Arctic, Antarctic, and some high mountaintops. In studies done in the Amazonian rainforest and in the African savanna, scientists found between 8 million and 20 million individual ants living in just 2 ½ acres (about 184 ants per foot)!

Despite their numbers, all ants belong to just one scientific family Formicidae, in the same order as bees, wasps, and several other insects. Only about 8,800 species have been identified, but it is possible that as many as 20,000 species may exist in the world and just haven't been discovered yet. All ants look very similar to the common North American species that we are familiar with, with the main species differences occurring in size, colors, and behavior, and minor species differences occurring in anatomical points that require a much closer look at the ants to identify them.

Ants are often grouped according to their behaviors: there are army ants, predator ants, fungus growers, harvesters, and weavers. Although some of these groups have different work in the

garden and thus play different roles in helping our gardens, many generalizations can be made about how ants are beneficial to plants.

Like worms, ants help to aerate the soil, which improves the soil and allows plant roots to grow easier. They can move as much as, or more than, the amount of soil as earthworms do!

Many species of ants are hunters that attack and eat other insects much larger than themselves. They will hunt insects as large as caterpillars and beetles. Some tropical species will also work together to hunt small animals. Hunting ants help to keep other insect populations in check.

Ants help plants more directly, also. When harvester ants bring back seeds to their nests to save for eating later, they disperse the plant seeds and effectively "plant" them. They often bring back more seeds than they can eat, so naturally those seeds that are not eaten may sprout. Some plants depend on ants to eat them, and have evolved to only germinate after an ant has manipulated them by eating part of the seed.

Ants can also help plants by pollinating the flowers, although they only do this limitedly, and are not considered as important pollinators as bees, butterflies and other insects.

Ants help plants directly through conscious agriculture, as well. Ants will cultivate a plant or many plants, protecting them from aggressive plants, tilling around their roots and practicing other agricultural techniques that we would be proud of. Ants farm plants for their sap (which is a sweet treat), for their vegetable matter (especially leaves), for their seeds or fruit, or even as food to feed their domesticated animals (especially aphids, which secrete a sugar when ants "milk" them) and fungi (which are eaten directly).

Ants will sometimes have many sources of food, and will undertake farming, ranching and hunting simultaneously.

In our fields, our ants especially love to cultivate favas and other beans and sunflowers...though they are opportunistic and will farm whatever plants grow naturally around their colony.

Although ants may cause some damage to plants when harvesting the plant's products or grazing their domesticated animals on "our" plants, the ants are, generally, very good farmers and ranchers: they usually always sustainably harvest (harvest in such a way that the health of the plant is not noticeably affected). Ants will usually cause damage to plants under situations when there is little biodiversity or biodensity in the field and they are forced to over-harvest from a few plants.

Ants rarely cause significant damage in gardens that also present reservation areas: ants are wild creatures, and prefer the wild places.

What damage they may cause can be controlled with careful planning and by managing a balanced ecosystem within the garden. Besides, there are plenty of creatures in the garden that love to eat ants.

Ants help more than they hinder, and should be encouraged to make their homes nearby.

We rely on the ants to care for our plants when we are not there. Together, we raise the beans, sunflowers and other crops in the field. Together, we care for the soil. We never till an ant colony if we can help it, and care for the ants when times get tough: we are sure to make certain that the ants have enough water and food, and that their colonies stay cool when it's hot and warm when it's cool.

Ants are very good at hunting, and will keep your field clean of those insects and arachnids that would eat your crops!

Ants have colonized our dryland lettuce and spinach: the ants are quite at home under the cool shade of the grass, weeds, spinach and lettuce! They are not eating the lettuce or spinach.

While some ants will hibernate during the winter, when temperatures and other conditions allow, ants will be busy all year long.

If you aspire to become a myrmecologist (entomologist who specializes in ants) or just want to learn some more about these oft-ignored helpers, observe them in your fields and research them in the library.

Recommended further reading:

Ants. Cynthia Overbeck, 1982. A good children's book with illustrative photos and information.

The Ants. Bert Holldobler and Edward O. Wilson, 1990. The "authoritative" book on ants presents a very in-depth look at ants from all over the world.

Praying Mantises

Praying Mantises belong to the order Mantodea, from the Greek for "prophet" or "soothsayer" due to their common pose of holding their large front legs in front of their head as if praying. Compared to other insects, the number of species of praying mantises is quite small, with only around 1800 species worldwide. North America has about 410 species, but very few of these live in the United States, as most praying mantises prefer a more tropical climate. There are no other types of insects in the order Mantodea, but praying mantises are closely related to grasshoppers, crickets, katydids and cockroaches.

Praying mantises are very easy to identify, if you can find them! They can be anywhere from 2/5 inch to 6 inches in length, although the American species are usually somewhere in between. They have a triangular head with large compound eyes located at the top two corners of the triangle. They can rotate their head farther than other bugs, allowing them to see all the way around them. As with all insects, they have six legs, but unlike other insects their front two legs are very large and barbed, reminiscent of crab legs. These are used to catch their prey, because praying mantises are carnivorous and hunt for their food. Praying mantises come in all different colors, and usually are very well camouflaged. One Colorado species blends in perfectly with the native grasses. Some praying mantises are multicolored and can even be bright pink; these colors help them hide on flowers.

Contrary to popular belief, female praying mantises do not always eat the male after mating, although this does sometimes occur. The babies hatch from their eggs about a month after harvesting, and they often resemble ants to protect them from predators. Just like their parents, the baby praying mantises eat other bugs, and sometimes even each other.

Praying mantises help in the garden by eating a wide variety of insects. They will eat any insect that will not make them ill, and will even eat other hunters such as wasps. The praying mantis usually hunts by sitting very still, and when it sees prey come within range of its claws, can strike within just 30 milliseconds! Praying mantises depend on catching large (relative to their own size) meals at infrequent intervals; they will eat almost anything that comes their way and is not too small or poisonous. Some larger praying mantises have even been reported to eat small frogs, birds, and lizards! Their other benefit to the garden, as with all insects, is their potential to feed other creatures in the garden. Although they have superb camouflage, they still sometimes become a meal to other hunter bugs, birds, and other creatures.

Recommended further reading:
Praying Mantis. Elizabeth J. Scholl, 2004. Children's book with excellent information and amazing pictures of praying mantises from around the world.
Grasshoppers and Mantids of the World. Ken Preston-Mafham, 1990. Contains information about grasshoppers, crickets, katydids, and cockroaches as well as praying mantises.

Skunks

Also known as polecats, these nocturnal animals can be alarming to find in your garden, though they are actually very helpful. Ernest Thompson Seton, who helped start the Boy Scouts of America, called them the "guardian angel" of gardens.

Within the skunk family, there are three main groups of skunks: the striped skunk, the spotted skunk and the hog-nosed skunk. They are all found the North America, although the hooded skunk also lives in South America. The striped skunk is the most familiar of these three, and the most likely to be seen. The spotted skunk is smaller and has white spots as well as stripes, and is more secretive in nature. The hog-nosed skunk is only found in a small area of the southern United States, and looks very much like the striped skunk except for the shape of its face.

Skunks were formerly scientifically classified in the same family as ferrets, weasels, martens, badgers, otters, and minks, but have recently been re-classified to their own family called Mephitidae. This is Latin for "evil smelling."

Yet we find them sweet.

Skunks are non-aggressive animals. They will never attack unless provoked, and even then they only attack with by releasing their foul odor, called "musk." They do not use claws or teeth to attack; these tools are reserved for digging and eating. The skunk is the only animal that releases musk in defense. Other animals produce musk also, but these animals use their musk to mark their territory, find a mate, or other such activities.

The skunk can release their musk with remarkable aim and quantity. When a skunk feels threatened, it will turn its back end, where the musk producing glands are located, towards its "enemy." It will usually give a warning before spraying, by waving its tail high in the air, hissing and stomping its feet. Then it constricts some muscles which causes the oily musk to spray out. Skunks can control this release of oil to form a stream or a spray, and can shoot it as many as eight times in a row for as far as twelve feet. Usually, though, they do not use so much musk, because then they would have no more left over if threatened again. Usually only a few drops are necessary to repel other animals (and people!). In keeping with their non-aggressive qualities, their spray is not usually harmful to any animal or person that is sprayed. The worst actual damage it can do is cause pain and temporary blindness if it gets in the eyes, but this wears off quickly.

Despite their foul odor, skunks are wonderful garden helpers. About 70 percent of their diet consists of insects, and they also eat mice. Although they are omnivorous, and will also eat fruits, vegetables, and grains, they are not likely to eat much in the garden as they prefer to eat insects. The most common species found locally is the striped skunk, which is the size of a large cat. You can imagine how many insects a hungry skunk then can eat in one night! Furthermore, other animals, like people, tend to get out of the way of a skunk, so a skunk's presence in a garden may even discourage other animals that might be more likely to eat the produce from hanging around.

The naturalist Enos Mills observed other animals avoiding the skunk (the only animal that did not in his observations was the porcupine).

Some people have domesticated skunks as house or security animals to great success. They are affectionate, loving and loyal creatures. Few people are not afraid of a skunk, but a tame one is loveable. A tame one trained to patrol at night and defend its territory is invaluable.

If you ever see a skunk in your garden, do not be afraid. If you do not startle it and let it go about its business, it will do your garden a great deal of good, and chances are you will never have to smell its presence. If you see a skunk in someone's house, remember it likes its belly rubbed.

Recommended further reading:
Porcupines and Skunks: Masters of Defense. Colorado Division of Wildlife, 2003. An informative introduction to porcupines and skunks.
Skunks. Wyatt Blassingame, 1981. A children's book with good, detailed information.

Birds

There are thousands and thousands of species of birds through the world, and our farm is home to many dozens of species. It is a great place for bird watching. Apart from admiring their beauty and grace, we observe what effects they have on the garden.

There are many kinds of birds, varying in sizes, habits, habitats, and countless other characteristics. Because each is adapted to fill a different niche in the ecology, each provides a different benefit to the garden.

Some birds are carnivores, and will eat other creatures. The tiny barn swallows can be seen on calm summer days swooping and speeding around the field, catching flying bugs.

Some carnivorous birds are larger, and so will eat larger creatures, including other birds, small mammals, and large insects. These large carnivorous birds include owls, falcons, and hawks. They have excellent eyesight, and can see their tiny prey moving on the ground while they fly high in the air.

These carnivores protect plants from the herbivores and omnivores that would eat them. Without plants, the entire ecology would break down: we all owe a debt to these protective carnivores that defend our planet's vegetation so well, but farmers perhaps owe them a great deal more. These carnivores protect our domesticated plants from the creatures that would destroy them.

So, as farmers, we must ensure that these carnivores have adequate habitat: nature will provide them food enough, but we must ensure that they have good places to sleep at night, to rest during the day and from which to hunt.

Some birds are omnivorous, and eat both bugs and plants. An example of this type of bird is the common robin.

While omnivores may sometimes eat your seeds or plants (we once had a robin follow us as we planted peas, eating every one we planted), they can be outsmarted, and their benefits in eating would-be harmful bugs and weeds certainly outweigh the danger of them eating your crops (for the expense of 1% more seed laid conveniently upon the ground, the robin was distracted from digging up our planted seeds). This robin later defended our crops against the weeds and insects that would have destroyed them.

Some birds will defend the crops against other birds and animals. Geese are excellent for this purpose, and will gladly keep your seeds safe on the newly planted ground without eating any of them.

Some birds are scavengers and necrovores (or eaters of the dead). These scavengers thrive upon the filth that would accumulate in the garden and include seagulls and crows. They protect your field against dangerous fungi, and other microorganisms.

Other birds are eaters of grain, others are eaters of fruits, others are eaters of nuts, some are eaters of sea life...the diversity and specialization of birds is astounding.

Flight is, truly, an advantage to both predator and prey! A barn swallow, a type of small carnivorous bird, rests from hunting on an overhead wire. From this height, it is safe from most of the carnivorous creatures that might eat it. A red tail hawk, a type of large carnivorous bird flies high above the ground upon which it hunts: its height above the ground makes hunting easier because its prey will not so easily see it.

Some farmers will buy chickens or geese to generate manure and to eat the weeds in their fields. Why buy birds when the native geese and other birds will do the same thing?

For more information on birds, we recommend joining any one of the many bird-watching societies, studying at the library, watching your own birds or visiting other farms. Lundberg Farms, a grower of speciality rices, relies on birds for manures. On their website, www.lundberg.com, they explain that "the role of waterfowl and other birds – cranes, egrets, ducks, herons, swans, geese, pheasants, red-legged dowitchers, and mud hens, among others – is vital to our soil building program. On winter flooded fields, they help decompose straw, reduce weed population, and provide natural fertilization. Several wildlife experts visiting our farms have been impressed with the variety and abundance of birds on our fields. 'We cooperate with wildlife groups by helping them count the birds populations and discussing ways to encourage their propagation,' Harlan Lundberg says. We post special 'No Hunting' signs around our property. The birds eat grain left in our fields after harvest. In the spring, pheasants and ducks lay their eggs in the lush vegetation of the purple vetch that grew on our fields during the winter."

Lundberg also rescues eggs from its green manure crops before they are tilled under. They report having saved the lives of some 24,000 ducklings alone since 1993.

Frogs and Toads

The peaceful songs of frogs and toads ease a summer evening into night, but these musical amphibious reptiles do so much more for farmers than prepare them for a restful sleep.

Not all reptiles are amphibious, and not all amphibians are reptiles. An amphibian is a creature that is at home equally in the water and on the land, and one that especially requires both aquatic (a word that means "watery") and terrestrial (a word that means "landish") environments for living and reproduction: amphibians require both land and water for living and reproduction.

Many creatures can be described as amphibious, not just toads and frogs. Most of these amphibians are reptiles (including not only toads and frogs, but also salamanders, some snakes and countless other kinds of reptiles).

Frogs and toads require water and land for both reproduction and living. Mating is typically undertaken on land, but the new generation of frogs and toads hatch in the water. Food is caught by adults on land, but the water provides not only the security required to avoid predators but also allows the animals to stay alive: without the watery environment they die.

Some frogs and toads do not swim much during their adult lives, but these species still rely on the water vapor from the aquatic environment of their youth for their health. Tree frogs and desert toads are some of the less aquatic of the amphibious reptiles, yet these too must find their way to the water if they are to lay the eggs that will yield a new generation of frogs and toads!

Young frogs and toads are called "tadpoles," and live entirely underwater. To get oxygen in their blood, they rely on cutaneous (a word that means "skin") respiration: through osmosis, oxygen enters the blood through blood vessels in the skin. Carbon dioxide and other waste gasses pass from the blood out through the skin. Adult frogs and toads have lungs with which they breathe, but they also use their skin.

Because of the semipermiable nature of their skin, frogs and toads are vulnerable to the innumerable toxic pollutants that may enter their aquatic and terrestrial environments. Should any poison enter the water, the toad or frog could not prevent it from entering their blood and killing them!

Many pollutants enter the waters and soils that toads and frogs live in. Some of these pollutants are from plants, others are from fungi, others still are from microorganisms like bacteria and viruses. The most dangerous toxins to toads and frogs come from humans: humans produce innumerable poisons and release them into the water.

Fertilizers, pesticides, herbicides, fossil fuels, sewage (including feces, urine and other wastes) and even industrial byproducts all contribute to the diminishing population of wild frogs and toads.

To protect their skin when not in the water, frogs and toads produce a mucus that covers their skin and prevents them from drying out. This mucus also protects them somewhat from the various toxins in their environment and, in the cases of some species, even protects them from being eaten! Some species of toads and frogs produce poisons that force what creature would otherwise eat them to throw up (thereby possibly saving the toad or frog's life, or at least possibly save the next toad or frog from looking too appetizing to the predator). These toxins are used by people for some medicines.

Some frogs and toads can change their color, others cannot.

Frogs and toads are cold blooded and require the environment to regulate their temperature.

Besides swimming and crawling, toads and frogs can move about by jumping and climbing. Some frogs and toads spend most of their lives in trees, nestled in the leaves; others spend most of their lives in the ground in burrows. All frogs and toads are carnivorous, meaning they eat other animals and cannot eat plants, fungi, bacteria or viruses (though some microorganisms or plant residues may be absorbed when the toad or frog eats their prey). Frogs and toads typically eat insects and arachnids, though some larger ones will set their sights on other reptiles (even snakes), mammals (including rats and – in very rare cases – small dogs or cats), or anything else that they can fit in their mouths.

Frogs and toads typically will hibernate during the winter. They can withstand temperatures that dip below freezing. Some can even become frozen and survive! Some can hibernate for months or years or decades, others never hibernate at all. Frogs and toads will also sometimes hibernate when their environment grows too dry.

Frogs are generally more adapted to more aquatic environments, toads are generally adapted to more terrestrial environments. Both are characterized by a similar anatomy and diversity, and are closely related.

Frogs and toads can communicate by tactile, visual and sometimes audible signals. Not all frogs and toads can produce sound, and sometimes sound production is gender specific. Sound is

produced by an air sack that lies beneath the jaw of the frog or toad: the sac is rapidly emptied through vocal chords.

Frogs and toads will lay eggs to reproduce and the eggs must remain under water to survive. Tadpoles (baby toads and frogs) are omnivorous. Some tadpoles will even eat other tadpoles!

Tadpoles look nothing like frogs or toads. Tadpoles are fishlike, having a long tail and no appendages. Gradually, the frog or toad will develop legs and lose its tail by "absorbing" it, using the molecules it was made of to make legs instead. The tadpole will develop lungs and eventually leave the water for the first time when they mature.

Frogs and toads are invaluable to the ecology and agroecology of a farm. Besides controlling the herbivorous pests that would eat our crops, frogs and toads entice other predators to come to the garden for a tasty treat. Frogs and toads burrow and stir the soil, improving the atmospheric content for the microorganisms and plants that live in it, and they perform many other "services" just by living, breathing and reproducing.

It is indeed a mistake to harm a toad or frog, and we bear it as a mark of pride that our farm is populated by these magnificent singers: because of their semipermiable skin, they thrive only in the cleanest of ecologies. We attribute our success to not applying poisons (herbicide, pesticide or fertilizers) to our fields, to adequately managing our sewage and wastes, to our providing of habitat for them to live and hunt, and to our conscious dedication to improving the lives and lots of all the creatures of our farm.

Prairie Dogs

Recently, we tried to adopt a prairie dog town. After contacting the various organizations dedicated to preserving the species, we found that it would be impossible to do so. In Colorado, prairie dogs are classified as vermin and you require the permission of all your neighbors and the county to import them.

The classification of some species as vermin predates our civilization and has its roots in the first biologists of ancient Greece. Attempting to organize the various kinds of life, they divided all living things into those that are beneficial to humanity and those that are dangerous to humanity.

The American naturalist and President Theodore Roosevelt improved upon the thousands of years of human experience by understanding that, while some species are dangerous to humanity, all species are necessary to the well balanced ecology and, if those dangerous creatures were kept in reserves designed for the maintenance of the surrounding ecology, not only would humans not be harmed by them but humans would be benefited by their ecological maintenance actions.

It is by this philosophy that lions, rhinoceros, African elephants (not Indian), and other creatures that actively seek out and kill humans are destroyed by governments whenever they leave their special reserves, and by the same philosophy that some plants which are poisonous to humans (such as tobacco, marijuana, coca, and others) are outlawed or else strictly regulated.

Prairie dogs, though, are unique among most classified vermin because they have no reserves that adequately allow them to undertake their ecological maintenance actions and private interests must see to the prairie dog's preservation because in public reserves the prairie dogs are still being destroyed.

Prairie dogs are classified as vermin because they – as all rodents – are capable of carrying and spreading human disease, including Black Plague. Ranchers classify them as vermin because of a fear that their livestock will cripple themselves on the prairie dog holes, though this is a mistake: no

animal usually falls into the well marked holes of the prairie dog; the jackrabbit (whose holes are purposefully obscured) is usually to blame for these injuries – even people have been known to fall down these rabbit holes!

Some ranchers classify them as vermin under the false belief that they compete with their domestic stock for food, but this is not the case unless the rancher is grazing rodents (such as rabbits).

Yet these creatures are essential to the maintenance of the short grass prairie ecology and are not only an asset to the farmer and rancher, but to the community of life that the farmer and rancher makes with the other living creatures of their fields.

Prairie dogs provide the hospitality of shelter to many predators when they abandon their burrows, their towns are favorite resting and mating spots for countless native species. Only when their towns are confined to too-small spaces or they have no predators to control their numbers will they decimate the local vegetation: a healthy prairie dog town has plenty of vegetation near to each hole.

It is even possible to plow next to the town of tame rodents who will joyfully devour the "weeds" in the farmer's fields, leaving their crops (largely) alone. Prairie dogs enjoy those crops which humans and their animals do not.

Prairie dogs do not live in the tall grass prairies and will avoid the tall grasses and crops that the farmer plants. They like to see what is around them.

Like bindweed (which also enjoys the hot, open places), prairie dogs are pioneer species. They take land that is otherwise undesirable, and by living there and making a home of it, they produce an environment uniquely suited for forests to succeed. Eventually, a prairie dog town will create such a plethora of flora and fauna that the town is forced to colonize new lands further away into the wastes and abandon the burrows of their ancestors.

Bindweed will shade the ground and reduce evaporation, reduce ground temperature and make suitable conditions for germination. When new plants grow up, they shade the bindweed (which tries to pull them down to preserve it's own life) and the bindweed eventually dies as it is overgrown by a forest.

Prairie dogs will colonize overgrazed land because they love the crops that the domestic cattle, horses, goats and other creatures leave behind.

Prairie dogs will turn the soil and improve soil moisture content.

They enjoy short grasses and many kinds of minor shrubs. They enjoy wheatgrass, grammas, buffalo grass, scarlet globemallow and rabbitbrush in the summer, and prickly pear cactus and thistle in the winter. Prairie dogs hate sagebrush, threeawn, prairie dog weed and horseweed. They hate even more those plants which grow tall above them and will try to cut them down. These tall plants they do not like to eat and in doing so, they create a mat which fosters the germination of larger and larger plants.

Their towns provide homes to most of the prairie's animals that prefer to live underground but do not dig their own burrows. Prairie dogs increase both the biodiversity and density of flora and fauna. What reasonable farmer or rancher wouldn't want that? The more biodiversity in the field, the greater their yields.

Farmers, though, classify them as vermin because they cut down the tall crops the farmer plants nearby. However, if the farmer plants crops that the dogs do not like to eat and do not present a security risk to the dogs (such as cacti, roses and other ground fruits; oaks, pinions and other tree nuts; etc.), the dogs are an essential asset to the farmer: the life the prairie dogs host in their town will wander all the farmer's acres.

The farmer can also construct barriers to the dogs, either walls of bushes and trees, or fences of metal (make sure to bury them in the ground deep enough that the dogs will not be tempted to dive under). New colonies or the expansion of the colony can be retarded by filling in holes.

The towns also improve the neighboring ecology by presenting a gathering place for many social animals. Prairie chickens and coyotes, especially, use the towns for mating and other bonding rituals. It is a gathering place for all the animals and interpsecies bonding. We have seen magpies bonding with the prairie dogs (one of the dogs nuzzling the birds with its nose, as it would nose-to-nose with another prairie dog, and the bird reciprocating with a love-peck). It is a place for snakes (who eat other more dangerous creatures for the farmer); it is a place where rabbits and deer would prefer to eat (instead of the farmer's fields).

There is little doubt that prairie dogs are vermin and are potentially dangerous to humans and human crops, but even vermin are necessary to the ecology. A farmer or rancher's wellbeing is directly tied to the wellbeing of their ecology and it is in the interests of every farmer to establish reserves upon their land and in coordination with their neighbors.

Those interested in learning more about prairie dogs would do little better than to read John L. Hoogland's *the Black-Tailed Prairie Dog*, or Dorothy Patent's *Prairie Dogs*.

13-Striped Ground Squirrels

When we get ready to celebrate our national Independence Day, we can't help but think of our little patriotic friends, the 13 Striped (or "Lined") Ground Squirrels, who are also called Patriotic (or "Federation") Ground Squirrels because of their fur's resemblance to our American flag. They are formally known as Spermophilus tridecemlineatus.

At one place we've farmed, there were many of these and other rodents because of the almost entire lack of predators. Our neighbors intentionally killed foxes, coyotes, lions, and many other creatures that would eat the rodents, and unintentionally killed hawks, eagles, snakes, and other predators that control rodent populations.

The farming methods of our neighbors were partially to blame for the lack of biodiversity, but the intentional and unregulated hunting of predators for profit, sport and to cause their extinction results in an ecology inhospitable to agriculture. Agriculture that increases biodiversity creates an environment conducive to agriculture.

Some of these predators have valuable skins but usually they are killed for a perceived danger to domestic animals. It is reasoned that wild dogs and cats could sicken domestic dogs and cats or kill domestic birds (or cattle); the "prairie goats" (antelope) and deer are accused of eating hay and other crops.

However, there are many ways to prevent agricultural damage from predation. Donkeys, llamas, roosters and other guarding and herding animals can work around the clock to protect livestock, and planting in beds and aisles, not tilling in autumn, letting weeds grow and conserving natural areas can reduce herbivorous predation.

The Federation Squirrel poses no real threat to crops, in fact, more than half of its diet consists of those herbivores that would eat our plants. Its favorite herbivores are grasshoppers and wireworms.

The remainder of their diet consists of seeds and grain, but these are more likely to be the seeds and grains from weeds. Besides, keeping them out of a wheat field is easy enough with Tull's tillage system.

Patriotic Ground Squirrels are omnivorous. Though they prefer mice and grasshoppers, they will eat also caterpillars, beetles, cutworms, ants, insect eggs, mice, earthworms, small birds, and each other. The vegetative portion of the diet includes seeds, green shoots, flower heads, roots, vegetables, fruits, and cereal grains.

They rarely drink water, depending instead on water contained in their food. They cache large quantities of seeds and grass, but never meat. The cached food may be eaten during periods of bad weather or in the late autumn and early spring when other food is scarce.

These brave defenders of our fields will also sometimes eat sprouts. The greatest damage we have received from them is the consumption of 4 squash sprouts – these were tried and disliked. No other damage has been incurred, and because we planted three squash seeds at a time, no loss to production resulted (squash will yield about the same number of fruits per acre with little regard to the number of plants per acre and it is wise to plant several at once in case of an adventurous rodent).

These animals seek their food close to their burrows. They mate after they emerge from hibernation in the spring; the female bears 5 to 13 offspring at a time. The 13-striped spermophile has 7 grayish-yellow stripes running down its back, interspersed with 6 stripes composed of spots. Its lower parts are fawn colored.

Patriotic squirrels weigh about 8 ounces (227 g) with a length of about 10 inches (25 cm) including a tail of 3 inches (8 cm). Each front foot has four toes with long slender digging claws. There are five toes on each hind foot.

The thirteen-lined ground squirrel is a grassland animal. Its original range was limited to the prairies of the North American Great Plains. When Europeans arrived and started clearing forests and establishing pastures, the thirteen-lined ground squirrel was quick to extend its range into the new habitat. Today, it ranges from central Alberta, Manitoba, and Saskatchewan in the north to Texas and New Mexico in the south, and from central Ohio in the east to Colorado in the west. The forests of the Appalachian Highlands and the Rocky Mountains have halted their east/west range expansion. There are a few colonies in Venango County, Pennsylvania, the result of introductions made in 1919.

Accordingly, a farmer who reforests their land with cherries, plums, acorns and various other trees can expect the populations of the Federation Squirrel to decline and stabilize as their cousins, the chipmonks, are currently lesser and more stable in the forested mountains.

The inconspicuous 2-inch (5-cm) diameter burrow opening is often concealed by vegetation and rarely has soil scattered in front of it like a woodchuck's burrow. They will sometimes "decorate" their doorstep with flowers or other pretty things that also function to hide it. The main entrance plunges down 6 inches (15 cm) or more before angling off into a complex system of galleries and side entranceways. The nesting chamber, about 9 inches (23 cm) in diameter and lined with fine dry grass, is located somewhat deeper than the main burrow system.

We have noticed they will choose as a burrow site a place that shields the burrow's sight from above, either by a large flowering plant or with a stone. This helps protect them from hawks, owls and other flying predators. They like to keep the entrance to their hole tidy and free of loose dirt by 'sweeping' with their back feet. Just inside is the entryway and then the tunnel turns in an 'L' shape. This shape helps trick pesky burrowing predators, like the badger, into thinking there is a dead end to the tunnel.

Mating activity begins within 2 weeks after the squirrels emerge from hibernation. Both sexes are sexually active for about 2 weeks. After a gestation period of 28 days, 3 to 14 (average 10) blind, naked, and toothless young are born. Only 1 litter is produced per year. Young ground

squirrels weigh about 1/10 ounce (3 to 4 g) at birth. Their stripes begin to appear after about 12 days and their eyes open 28 to 30 days after birth. Young squirrels are weaned and on their own after 6 to 12 weeks, when they dig their own burrow, usually within 100 m of where they were born.. Thirteen-lined ground squirrels are sexually mature at 9 or 10 months of age.

They are true hibernators, allowing their body temperature to drop to just above freezing and their heart rate to drop to as low as 20 beats per minute from their usual 200. During hibernation, S. tridecemlineatus can lose up to 1/3 of its body weight. Food caches are consumed during hibernation arousals, especially just prior to emergence.

Thirteen-lined ground squirrels have excellent senses of vision, touch, and smell. They use alarm calls and other sounds, as well as using special scented secretions, to communicate with other squirrels. They rub glands around their mouth on objects to leave scent marks. They also greet one another by touching noses and lips.

Having grown up in safety, our patriotic friends were not shy at all and would come right up to you as you were working to ask you what you were doing! They had not learned to fear the tall grasses and weeds that normally protect our crops. Creatures are normally afraid of the snakes, coyotes or other predators that might be hiding in there, but out there where most of the predators had been killed, we could not rely on fear to protect our plants. It's well enough: as soon as the predators return, the rodents will learn quickly to fear them, and teach their young to as well.

Yet it is true that these squirrels like grain. 12 of them lived near to our barn where our animal feed was made and stored. It sounds like a disaster in the making, but we were able to protect our barn cheaply and effectively, without resorting to killing these magnificent creatures by simply constructing the building solidly. We do not resort to poisons, gunfire or traps, we do not attempt to kill them at all!

Further control was undertaken by creating habitat and refuge for the predators.

Further suggested reading may be obtained from the Internet Center for Wildlife Damage Management (who advocates the extermination of the Squirrel).

Treat every creature – animal, plant, microorganism – with dignity and respect: they are conscious beings, and you share your noble ancestry with them; the mental fitness of species; the other animals that undertake agriculture; the organization of agroecology

It is important to remember the research of Darwin and others that demonstrate how plants, despite their lack of a nervous system, are able to think and communicate with each other through chemicals and touch, and that they should be treated with the same dignity as any animal or any other living thing. Animals and plants are similar enough that Dr. John Kellogg[350] gained, through

[350] Jethro Tull compared the stomachs of animals to the roots of plants, and was not the only one to understand things so: Dr. J. H. Kellogg, of the Battle Creek Sanitarium, through his experiments and in coordination with Louis Pasteur, discovered a similarity between the digestion in the animal stomach and the fertility of the soil: both indiscriminately absorbed nutrients (and sometimes poisons) through villi, both were subject to the flora living about their villi for either their health or their sickness. The structural similarity of plants and animals in their gut is striking, but lends understanding to how similar plants and animals are.

excellent medical research, an understanding of human nutrition, physiology and metabolism that is easily applied to both plants and animals—and which explains how Jethro Tull's method brings plants to eat more food.

The creatures of the world share your noble ancestry, and whether you hold that God made them or they evolved from a like ancestor, this alone merits the dignity by which you should treat them, and by which you will earn their friendship in your fields, and the greater profit from their friendship. Though you require your fellow creatures for food, fiber and energy, for workmates and companionship, you should respect them as living beings worthy of honor. Though you command them and they are within your power, use your power over them as you would use your power over your children: to help them achieve the full potential of their birthright.

> "Food is to the body what earth is to plants. The food is the soil out of which the body grows. The four million villi of the small intestine are the rootlets which suck up the nutrient material prepared by the digestive ferments to nourish the tissues" — *Autointoxication or Intestinal Toxemia*, page 45.

Dr. Kellogg explains that, whether in agriculture or in medicine, microorganisms can be helpful or hurtful: microorganisms can deplete the soil or make a person ill, however, under correct conditions, microorganisms can be as helpful to plants as, under correct conditions, microorganisms can be helpful to animals.

Microorganisms in the soil can improve the fertility of the soil (or, at least, improve the ability of plants to benefit from what fertility there is inherent within a soil), and that access to Oxygen, water, Carbon Dioxide, Nitrogen, and other atmospheric components aid these microorganisms.

> "The rootlets of plants are surrounded by bacteria that perform a useful office for the plant by fixing the nitrogen of the air and converting it into compounds that the plant can use in the manufacture of protein and plant protoplasms.
>
> Bacteria are evidently necessary for the promotion of plant life through the making of soil and the fixation of nitrogen, although it was long ago shown by the Pasteur Institute that some plants may grow in a perfectly sterile medium." —*Autointoxication or Intestinal Toxemia*, pages 30-31.

The reader will note, as Dr. Kellogg intended, the difference between the possibility for life without bacteria and the reality of life with bacteria: though Dr. Kellogg goes on to say that the presence of bacteria in animal stomachs are "accidental" and not essential to animal life, the presence of microorganisms in the soil and in the stomach enable the generation of helpful—or harmful—chemicals. Animals—and plants—rely directly or indirectly upon microorganisms for their nutrition: while a ruminant would be able to survive upon a much modified "artificial" diet if it had no microorganism in its stomachs, it would find surviving on its natural forage difficult or impossible without the help of microorganisms. So too, do plants rely upon bacteria—or else upon the artificial diet provided by their human caretakers. The human body relies upon the actions of "helpful" microorganisms for nutrition, and so should humans rely on microorganisms for the nutrition of their plants: Tull's method encourages feeding the soil to feed the plants; Dr. Kellogg suggests the feeding of the stomach to feed the animal. Dr. Kellogg's book, *Autointoxication or Intestinal Toxemia*, is strongly recommended further reading.

Like Dr. Kellogg, Dr. Sigmund Freud gained important understandings that are applicable to animal and plant behaviorology (which are directly applicable to an understanding of agroecology). They are highly suggested further reading as they form the basis of an understanding to the mental fitness of species.

It is presumed that the reader has a familiarity with the work of Dr. Freud, but for those who do not, the following simplification will be made against the reservation that the reader should familiarize themselves with the work of this important physician: 1) all animals have three sections of "mind," the conscious (that which deals with the external world), the superconscious (that which deals with the internal world) and the unconscious (the inner world). The superconscious and unconscious constitute the "preconscious" mind. 2) All animals attempt to internalize the external world through a process of emotion and tool-making (even if those "tools" are their appendages). 3) The purpose of all life is to replicate itself, and therefore the purpose of "mind" is for replication: the mind is a sexual organ, able to teach the adaptive behaviors unique to the species to the next generation (thereby "replicating" the previous generation), able to seek and identify suitable members of the species with which to physically replicate, able to adapt to the world to ensure that the mind's body will be able to replicate (and not die), and able to adapt the world to the mind's body to ensure that the mind's body will be able to replicate (and not die).

By exploring the way by which people might internalize the external world through a process of agriculture, Freud demonstrated the mechanism by which humanity is cultivated by cultivating the soil. Yet long before Dr. Freud's first experiments, even Columella understood that the nature of people is reflected in their agriculture. Any animal[351] that undertakes agriculture causes upon their agriculture a reflection of their mind: the very instant when agriculture is undertaken by any species, the ecology begins to behave differently and can be said to have conscious and preconscious food acquisition. Without the actions of the agriculturalist, the ecology presents an entirely preconscious system of food acquisition[352]. It is only by conscious efforts that an ecology is formed into an agroecology.[353]

[351] Many animals (beside humans) undertake conscious food production. Hymenoptera (the bee, wasp and ant order) is a family renowned even by humans for its conscious food production. Indeed, Hymenoptera produce food with at least as much skill as humans: ant edible fungi production and ant aphid ranching are nearly identical to human edible fungi production and human dairy animal ranching; the fermentation of pollen by bees is so similar to the human fermentation of grain that bread making and honey making can be analogous. Even elephants will pile bananas in the sun to ferment alcohol in almost the same way that ancient humans used to brew beer, and squirrels improve the digestibility of and store tanin-high seeds through treatment similar to how humans improve the digestibility of cabbages and bitter roots (by burying them during the winter). Dolphins "round-up" herds of small fish before harvesting them almost identically to the way humanity rounds-up herds of wild animals; felines (major and minor) will consciously study the habits of their favorite prey—and teach those lessons to their kittens. So many species undertake a conscious food production that the reader will need to excuse a focus on humans: in this concluding chapter as much effort as is possible has been made to show the generalities of conscious food production which exist throughout the Animal Kingdom, but examples made generally focus on the conscious food production of humans.

[352] An excellent example of preconscious food acquisition would not be the feral cat stalking prey, nor indeed the actions of most carnivores (carnivores rely heavily upon their conscious mind to learn and predict the actions of their would-be food). Perhaps the best example of preconscious

Ecologies evolve into agroecologies from the interaction of the conscious mind of the agriculturalist with the world-tool. The animal that practices agriculture creates a system of food production that has both conscious and preconscious actions, and a structure and character similar to their consciousness[354]. To say it another way, an *ecology* is the result of the influence of innumerable creatures acting preconsciously. An *agroecology* is the result of the influence of one or more creatures acting consciously for food production in coordination with those innumerable preconscious creatures.

Under this technical understanding all agricultures are similar to the processes of the mind. As in the human mind, the effects of all preconscious actions (the actions of all creatures in the ecology acting preconsciously for food production) are similar or identical, and the effects of all the conscious actions (of all the creatures in an ecology acting consciously for food production) are similar or identical. As in the human mind, all conscious actions are aimed towards the betterment of the ecology; all preconscious actions of all creatures are, generally, for the preservation of the preconscious individual within the ecology. Conscious agriculturalists are guided by their self-interests (and limited by their skill and knowledge) towards the improvement of the ecology, preconscious food acquirers are guided by their self-interests into inadvertently improving the ecology.

And because it is known that all minds are organized in a similar fashion through studies on the psychology of humanity's fellow creatures, it becomes apparent that the other species which practice agriculture—and indeed all species—have their interests more or less aligned with those of humanity. The interests of every individual lie in the betterment of the whole.

Montesqueiu's theorem directs the agriculturalist to improve the ecology as much as possible. The interest of the agriculturalist (conscious mind) to bring the natural ecology (preconscious mind) to develop a system of agriculture that is efficient to the point of being self-sustaining. To do so, the ecology must be generally improved: the interests of the individual lie always in the betterment of the whole.

food acquisition is the beaver. Beavers build dams and canals the same way that people do—and for many of the same reasons: beavers build dams not only for protection of their homes (as moats) but as fortified access to their favorite feeding areas from their homes. While securing better access to their food, they also to foster the growth of their favorite trees (willows, aspen and birches, especially) and improve the soil their forest depends upon. Another good example could be the rudimentary human mushroom production that existed in the early years following the Middle Ages: edible mushrooms inadvertently grew on the waste products of the animals humans had domesticated.

[353] To use the beaver and mushroom examples again, each could be brought to conscious food production: the mushrooms *were* brought to conscious food production when the mushrooms were domesticated—the humans learned how they grew and then purposefully grew them, and later improved the methods of growing them. The beaver could consciously begin to cultivate their favorite trees by thinning their competitors, or use their dam's water to purposefully irrigate saplings, or build lodges for the growing of trees (not just for shelter)—then they could eat from the safety of their moat.

[354] Dr. Freud's lifetime work was to repeatedly demonstrate that consciousness has a similar structure and character in all species.

Objections can be raised to this understanding of the interaction between agriculture and ecology. These objections usually are based on the observation that the agricultural systems of two different species are usually competitive. This is true: the agricultures of two species generally do compete; ants and humans often compete for resources and act as pests to each other. However it is important to remember that, as the sophistication of the ant and human agriculture improve, and as the two species learn how to work with each other, competition is reduced to tolerable or unnoticeable amounts: very few, if any, humans will complain that bees are harvesting pollen from their fruit trees—even if their trees require the pollen to produce fruit. These enlightened humans understand that the cost of the bees' consumption is outweighed by the production of fruit. Enlightened humans are capable of understanding how to adapt to the environment so that they do not compete with the ants, and are more helped by ants than harmed by ants. Likewise, enlightened ants will alter their food production to have the human work for them!

Another objection is based on the observation that a conscious and co-operative relationship between two species (for example, ants and humans) is prohibited by an inability, on behalf of both species, to communicate with each other and an inferior ability of one of the species (for example, ants) to recognize, learn and adapt for coordinated efforts with the other (for example, humans). However, the human (or more advanced species) may take a leadership role when both species seek to work in harmony: it is the obligation of the human, who can recognize, learn and adapt for coordinated efforts better than the other species, to treat the other species' conscious agricultural efforts as they would their own. The human must guide the other species, who can preconsciously adapt to stimulus from the human, into a more harmonious relationship with the human's agriculture—and recognize the other species attempts to similarly provoke preconscious adaptation upon them as "communication" —even if those species do not mutually understand the human's actions are to provoke preconscious adaptation as "communication."[355]

The human, by their ability to understand the minds of many species, needs little ability to communicate to the other species: the human can bring the ant—or any other species—to do what is required for the betterment of the ecology without language. The human can encourage ants to share the burden of tending plants or the burden of tillage.

Objectors should not doubt the ability of humanity to bring its fellow creatures to do what humanity perceives is the best for the environment. Sometimes, the ability of the human to bring other species to submission is quite advanced: a human is able to bring bees to become peaceful during a raid of their honey and bring a horse to drag heavy weights. Sometimes the ability of the human is primitive and limited to only being able to trap or kill a creature that is having an adverse effect on the environment. The ability of humanity can be sublime: the human is able to induce the snail or elephant to preserve their crops by providing more palatable alternatives, the human is able to induce predators (of all sizes, from as small as the retrovirus to the greater hunters like ladybugs and mantises to the great felines and canines) to hunt in the field by providing adequate vegetation

[355] The ants, for example, will become ferocious if their agriculture is threatened and attempt to force unconscious adaptation of the human to avoid disturbing their agriculture by, for example, biting and stinging the human: the human is able to recognize this communication and decide whether it is in the interests of the agroecology at large to disrupt the ants' agriculture. The human is, no matter what they decide, powerful enough to force the ants to take whatever action the human desires. The human must account the efforts of the ants as beneficial, and attempt to work with the ants: the ants provide work that the human then need not provide, and are more able to undertake some tasks than the human.

for an ambush or shelter. The human can—and has—even domesticated bacteria, snakes and leaches for medical purposes! The human has brought pumpkins to grow vertically instead of horizontally, brought the corn to entirely depend on the human for reproduction (triumphing over that most basic instinct!), and brought the hen to allow the human to take her eggs.

Certainly, the human, faced with a conscious species that is threatening the mutual efforts of both the human and themselves, can react in a way that brings both species into harmonious action. When a human farmer sees ants that are ranching aphids on their crops, the human immediately fears the ants' ranching will become unsustainable (however rarely this actually happens). The concerned human farmer can then observe the environment to learn why the ants would be encouraged to expand production unsustainably (perhaps the ants have no other source of food, or the ants perceive an excess of pasture, or there are no predators to the aphids or ants, or some other reason) and take action to make sure that the efforts of both the ants and themselves are in line with the interests of the ecology.

In this way, a crop of sunflower seeds can be tended by the ants (and not the farmer) or a plague of insects can be reduced or prevented by the innumerable friends of the farmer in the garden.

Every creature is guided by their self-interests to act as consciously as possible towards the improvement of their ecology through agricultural actions. When the environment is sustainably improved for one species, it is sustainably improved for all species. When the environment is unsustainably improved for any species, it is unsustainably improved for all species: an ant colony that unsustainably ranches aphids destroys the ecology as quickly as a human who ranches their cattle unsustainably, or farms their crops unsustainably.

Increasing the biodiversity and biodensity in the field—and then caring for all the creatures in the environment as if they were domesticated crops and animals—is the only sure way to improve the sustainability of harvests. *Increase the biodiversity and biodensity in the field, increase your yield.* Darwin unequivocally demonstrated that biodiversity is an asset to the world. The lives of every creature depend on countless others; whenever one species is lost (to agriculture or to the world), the impact is disastrous.

But do not question, *what is the purpose of this plant (or animal)?* This way of thinking demonstrates unfamiliarity with nature. No creature has a purpose. A squirrel's purpose is to be a squirrel, and to ensure more squirrels carry on being squirrels after it dies; a human's purpose is to be a human, and ensure that more humans carry on being human after they die. Every creature's interests are in the welfare of the ecosystem at large, and every creature has unique abilities in achieving its interests. Ultimately, this requires that every creature perfect their interaction with their environment.

Marvel at the glory of creation by witnessing how all creatures cooperate towards this goal of perfection: the ants, ranching their aphids or farming their fungus, the bees fermenting their pollen and the people tilling their fields all work in harmony, improving the land for all creatures—not just the ones they've domesticated. Look at how the feral cat or the sparrow, by hunting in the field, maintains by their predation that careful balance on which all creatures depend for their air, water and food and improve the efficiency of all other creatures. How even the unconscious beaver improves the world they and all their fellow creatures depend upon!

When a human irrigates their field, all plants and animals there benefit from the water; when an ant grows fungus to eat, the whole soil benefits. When a human encourages migrating birds to land in their winter fields, the human encourages a preconscious fertilization of their land.

Humanity's dependence on other creatures is no less or greater than any other creature's dependence on humanity. As the spiders seek shelter in the homes of people in wintertime, as the

ants are sometimes forced to forage in a person's fields when their own crops fail, humanity just as often looks to their neighbors for aid.

From time to time, foul weather falls on humanity's crops. In a biodiverse field, strong plants shelter the weaker plants and animals and little or no damage is incurred. From time to time, disaster strikes us all...no creature is immune, from the squirrel or ladybug to the elephant or human being. From time to time, we all require shelter and protection from those fellow creatures that are able to weather the storm better than we are.

Without biodiversity and biodensity, the burden on humanity to secure a harvest is immense and expensive...this cost is often unsustainable for any long period of time. The interests of any civilization lies in the maintenance of its agricultural land by the lowest-cost and for the longest term possible: the long term interests and short term interests of every person and every civilization are the same. The success of civilization depends on the peaceful cooperation of every person and every creature.

There is no reason why, with the careful skill of human hands, wolves cannot lie down to sleep in a herd of calves, why fields must be overwhelmed by pestilent thorns that are abhorrent to all creatures. There is no reason for humanity to break their backs tilling the soil when they have machines; there is no reason to work the machines when the agroecology is well-tempered. Fukuoka did not lie when he reported that Eden's gates are open. Humanity is free to return, free to enjoy the bounty without labor. All debts that were owed have been repaid through humanity's worship of creation by science. We may regard Jethro Tull as a herald for a new age for humanity when food grows without care, when famine and sickness are no more. We may well ask, what wonders can we do without these old hates to burden us? What glory can we achieve now that we are freed from the fields of labor?

There is so much more work to be done, not only in the continued worship of the world through scientific observation, but for the progress – and process – of civilization. Welcome the first fruits of the scientific enlightenment by remembering fondly those sublime flowers of agroecological science, Tull and Fukuoka.

A middle path: combining the methods of Jethro Tull and Masanobu Fukuoka

Masanubu Fukuoka, a soil scientist in Japan, independently developed in the 20th Century a system of agriculture similar to Tull's 18th Century system. Yet there has been discussion recently that somehow Fukuoka's method and Tull's method are opposites. Though Tull and Fukuoka might seem opposed, they are spiritually similar and the two men personally have as much in common as their methods.

While not perfectly aligned, by looking at the qualifications by which Fukuoka establishes his method to meet the same problems that Tull observed, it is possible to understand the spirit of Fukuoka's system is identical to Tull's. Though lacking Tull's insights, Fukuoka's brave experiments drive him in a similar direction as Tull. Fukuoka, by directing the farmer to "do nothing" errs as much as Tull errs in directing the farmer to "do everything." Fukuoka's Buddha would point to a middle path as much as Tull's Jesus might advise Tull to become more tolerant of God's creation.

We will summarize Fukuoka's method and compare them with Tull's.

Fukuoka's method has four principles: 1) no tillage, 2) no fertilizer, 3) no herbicide (including weeding), and 4) no pesticides.

No tillage.

Fukuoka's arguments against tillage will be addressed individually.

He says that it is not good because it selects for stronger weeds, but this is simply not true if it is undertaken regularly, as Tull or Columella advise: then, no weeds are selected for because they are all destroyed except those which grow among the rows, and these, being random, do not especially improve their species of weed. Till in the aisles and between rows when nothing grows or where nothing should grow and you won't be selecting for stronger weeds, just better placed ones: weeds are unable to choose where to grow the following year when you move the beds and aisles.

Fukuoka also says that tilling reduces porosity of the soil, "When a farmer plows his fields and turns the soil with a hoe, this appears to create air spaces in the soil and soften the dirt. But the effect is the same as kneading bread: as the farmer turns the soil with his hoe, this breaks the soil up into smaller and smaller particles which acquire an increasingly regular physical arrangement with smaller interstitial spaces. The result is a harder, denser soil. The only effective way to soften up the soil is to apply compost and work it into the ground by plowing. But this is only a short-lived measure," (Page 104, The Natural Way of Farming, by Masanobu Fukuoka, 1985, translated by Frederic Metreaud).

On this point we must admit that Tull and Fukuoka speak of different things: Fukuoka's impression comes from a kind of tillage Tull does not advocate. In fact, Tull advocates against this kind of tillage, presenting a hoeing agriculture instead. Tull agrees that bad tillage hardens the soil, and thus it is necessary to till regularly and frequently. Modern research (espcially that of Goss, et al.) agrees with Tull: well-tilled fields are looser, have more organic matter and larger pores than poorly or untilled fields. Thus we see that while Fukuoka argues against tillage, so does Tull, and Fukuoka says nothing bad against hoeing.

Fukuoka argues against plowing shallowly: "Farmers usually plow the soil to a depth of about four to eight inches, whereas the roots of grasses and green manure crops work the soil down to twelve inches, fifteen inches, or more. When these roots reach down deep into the earth, air and water penetrate into the soil together with the roots. As these wither and die, many types of microorganisms proliferate. These die off and are replaced by others, increasing the amount of humus and softening the soil. Earthworms eventually appear where there is humus, and as the number of earthworms increases, moles begin burrowing through the soil. The soil works itself. The soil lives of its own accord and plows itself. It needs no help from man...Man has restrained the hand of nature, and taken up the plow himself. But this is just man imitating nature...he will certainly never create soils more perfect than those of nature." (Pages 104-105, Natural Farming).

Here again Tull is in agreement. Yet while Fukuoka argues that tillage can never be deep enough, and is not even required, the evidence of Tull demonstrates that, while not required, tillage does improve the health of the soil and the plants that eat it. It is not necessary to till deep enough if you will simply till deeply in aisles, so the plants can graze upon it.

Fukuoka argues that tillage is unnatural, but this is clearly in error as demonstrated by Tull's essay on the origins of plowing deriving from observations of pigs. Earthworms, ants, beavers...countless creatures undertake tillage. The frost in winter causes tillage. Why cannot humanity as well? Why cannot humanity do better than the other animals at this most essential task?

Yet perhaps this is a misunderstanding, and we must give Fukuoka credit: perhaps he intended to say that tillage destroys biodiversity, which harms the field. This is undoubtedly true, but if reserves of wilderness are maintained, then the benefits of tillage and the benefits of nature can

be had at once. These reserves can be either entire beds dedicated to wilderness, or designed to enclose some natural resource on the farm. In any case, though Tull and Fukuoka cannot be reconciled upon this point, they can find compromise through natural reservations.

No fertilizer.

Fukuoka flatly argues against fertilizer (pages 108-111, Natural Way of Farming). Even when it is in the form of plowing, and especially when plowing is used (as Jethro Tull directs) to introduce the fertilizer nearer the roots. This comes from Fukuoka's perspective that you can get a yield of crops without any fertilizer.

Tull is not in disagreement: fertilizer is not necessary. Though Tull does not prohibit fertilizers, the cost of fertilizers are usually more than the benefit they provide to the field.

Fukuoka warns that because fertilizers accelerate the growth of crops and do not provide balanced nutrition to the crops, fertilizers weaken the crops. Modern botany agrees with Fukuoka. Though Tull hated fertilizer for the cost, he should have also hated it for the damage to his plants.

Yet it remains true that Tullian fertilization (through tillage) provides all the nutrients a plant requires and there is no plant malnutrition. Fukuoka hates the use of chemical fertilizers that provide only one, two or sometimes three nutrients. Animal fertilizers are not much better (though Fukuoka did not directly raise objections to them), as they provide far too much protein and imbalanced nutrients into the soil. Tillage alone provides balanced nutrition and answers Fukuoka's objections.

Fukuoka also argues that ammonia and other chemical fertilizers are not very effective because of the numerous factors that either reduce or eliminate their potential effectiveness. Modern science agrees with Fukuoka, but, because Tullian fertilization (through tillage, or tillage with plant manure) uses natural cycles, Tullian fertilization accounts for all these numerous factors and reaches its potential effectiveness. Tull does not rely on ammonia or other chemical fertilizers, and even argues that manure is both expensive and unnecessary.

Fukuoka argues that chemical fertilizers potentially damage the soil by causing acidification, water poisoning, salinization, and other problems. Science demonstrates that these are concerns, but do not occur with Tullian tillage.

Fukuoka argues for the use of green (plant) manures (page 112, Natural Way of Farming). Tull heartily agrees...so long as it comes at a good price because the farmer can do without it entirely. Here, Tull does less than that great do-nothing, Mr. Fukuoka! Though Tull did not have experience with chemical fertilizers, his method and ethic is so against unneeded additives to the soil and the economical use of what additives are given to the soil (i.e. manure) that it is hard to believe that he would ever argue for the use of chemical fertilizers. Tillage is cheaper, more reliable, more effective and safer than chemical fertilization.

No Weeding.

Surely there disagreement on weeding? Tull flatly accuses weeds of stealing the food, light and air of domesticated plants. Fukuoka (pages 112-115, Natural Way of Farming) claims weeds are valuable, not only as habitat for wild creatures, not only as edible foods, but as green manure.

This dispute is easily compromised: upon experimentation, farmers will find that it is most profitable to allow weeds to remain in reservations and domesticated. It is as if wild ducks came to live in a chicken house: the ducks provide higher quality eggs and earn as much or more profit than the chickens. Don't shoo away the ducks, give them food and shelter, and they will earn it.

Weeding between rows is not costly with the use of a cultivator attachment to the tractor or draft animals. Hand-weeding among the rows is costly, but under Tullian management is easily performed by few enough laborers that it is worthwhile. Yet, under the Tullian method, few weeds remain to sprout up among the crops. In the reserves will grow many valuable plants: domesticating them and sowing them like any other desireable seed will result in greater profits.

In experiments, we have tilled only in aisles and not between rows, and the weeds accomplished little harm. This is good news to those who cannot afford the labor, animals or tractors to till effectively between the rows and should stand to encourage even those farmers who can afford a cultivator implement for their animals or tractor. Still, better yields are gained with weed control. It is up to the farmer to decide whether the weeding is worth the price.

For our part, we have learned that reserving 20% of the field is best. Combining the 20% in a single reserved block is better than dividing it out among the crops in an every 5th bed / aisle pair reservation, but there are benefits to having reservation near to the beds and a system of many smaller reserved blocks radiating from a larger reserved block evolves as the farmer also tries to protect corridors for wildlife travel. It is very important to reserve key natural resources (such as creeks) upon which wildlife depends. The farmer would be wise to undertake trials and observations to learn where and how much of their land to reserve.

The UNFAO recommends shelter plants for snails to be centrally located for the convenience of the snails. This is true, too, for wild animals. Putting shelters for them in central locations allows them to better access your field. Putting shelters for carnivorous protectors far off to one corner of a field does not do much for the far corner unless the field is very small.

Care for the reservations. Remember that every species has unique needs and that, if the plant (or weed) on which they depend for shelter or food does not exist in the field, they will die. Every species is important, it is therefore essential to identify keystone species and individuals within the field (the species and individuals that are essential or very important to one or more types of life: in example, some butterflies will only lay eggs on thistle, or many animals might seek shelter in a large alfalfa bush—both the thistle species and the individual alfalfa bush are keystones).

No pesticides.

This is a different kind of disagreement. While Tull is no friend of wild animals in the field, he is no friend to domesticated creatures either. And, while Fukuoka is a friend to animals in the field, he does not actively try to help them (some friend indeed!).

Fukuoka's principle objection (pages 115-119, Natural Way of Farming) against pesticide is the danger of the chemical pesticides to not only the environment, but to the people who depend on the environment. As Tull never saw the horrific poisons to which Fukuoka objects, it is difficult to say his opinion on the matter. Yet we are sure that Tull would not have minded those animals that would have defended his crops and would have objected to the poisoning of his drinking water; at any rate, he would have objected to the cost of the pesticides. There are better ways to defend your crop of food than by poisoning it in a way that destroys your water: to avoid starvation only to die of thirst is no victory.

Understanding the role and nature of every individual in the field within the agroecology is difficult, but it is the farmer's job as much as tilling in the aisles regularly, planting and harvesting. All the farmer's efforts in planting and tilling will come to nothing if they know nothing of the ecology that can – potentially – destroy or save their harvest. Equally important to a knowledge of what is in the field is a knowledge of what is going on beyond the fences of the farm.

Minor principles.

Both Tull and Fukuoka agree on intercropping. Both believe that agriculture is a service to God, Fukuoka because of his Buddhism, Tull because of his Christianity. Both were active in their religions, Fukuoka writing poetry for his Monastery, Tull playing the organ at his Church. Both believe that the foundation of agriculture is in the feeding of plants, and that the healthier the plant, the better the agriculture. Both attempted to teach their neighbors a better way of farming—not for poor business sense (doing so created competition), but out of a love for people.

Warning to Farmers

We will repeat Tull's warning (in his Jethro Tull's Suppliment) against wholly converting a farm to the new method before trialing it. It is somewhat difficult to master if not well studied, and to use a small part of the land as a teacher while the remainder continues in the old, poorer methods, will result in more profit later and much less frustration. Practice it and you will certainly master it, but if you have any friends who have already mastered it, seek their mentorship if they will give it to you. "I am far from advising any gentleman who has a good tenant to turn him out in order to practice agriculture or rashly change that scheme he does already in practice if it brings him good crops... but by all that I hear of, there are too many who do not enjoy either of these two happy circumstances and I am afraid that it will not be long before few or none will enjoy them. I wish that itme may not come before gentlemen have made themselves perfect in the theory and practice of the most profitable agriculture, whatever it may be."

This said, we are ultimately convinced by our own trials that Tull's method is supremely profitable, so much so that we have even undertaken the effort to republish his book.

Masanobu Fukuoka greens the desert

An interview with Masanobu Fukuoka, by Robert and Diane Gilman of the Context Institute in Autumn of 1986 (page 37, Sustainable Habitat (IC#14)) while he visited the Abundant Life Seed Foundation in Port Townsend, Washington demonstrates the can-do confidence that farmers will require in the years of climate change to come and have earned through the works of Tull and Fukuoka. Through Tullian and Fukuokan systems, deserts can be greened and, though less rain is falling and the climate is not as generous as it was, as Columella points out, humanity's destruction will not be due to the fury of the elements, but due to our own faults.

Robert: What have you learned in your 50 years of work about what people could do with their agriculture?

Masanobu: I am a small man, as you can see, but I came to the States with a very big intention. This small man becomes smaller and smaller, and won't last very long, so I'd like to share my idea from 50 years ago. My dream is just like a balloon. It could get smaller and smaller, or it could get bigger and bigger. If it could be said in a brief way, it could be said as the word 'nothingness.' In a larger way it could wrap the entire earth.

I live on a small mountain doing farming. I don't have any knowledge, I don't do anything. My way of farming is no cultivation, no fertilizer, no chemicals. Ten years ago my book, One Straw Revolution, was published by Rodale Press in the United States. From that point I couldn't just sleep in the mountains. Seven years ago I took an airplane for the first time in my life and went to California, Boston, New York City. I was surprised because I thought the United States was full of green everywhere, but it looked like death land to me.

Then I talked to the head of the desert department at the United Nations about my natural farming. He asked me if my natural farming could change the desert of Iraq. He told me to develop the way of changing the desert to green. At that point I thought that I was a poor farmer and I had no power and no knowledge, so I told him that I couldn't. But from then I started thinking that my task is working on the desert.

Several years ago, I travelled around Europe. It seemed to me that Europe was very nice and beautiful, with lots of nature preserved. But three feet under the surface I felt desert slowly coming in. I kept wondering why. I realized it was the mistake they made in agriculture. The beginning of the mistake is from growing meat for the king and wine for the church. All around, cow, cow, cow, grape, grape, grape. European and American agriculture started with grazing cows and growing grapes for the king and the church. They changed nature by doing this, especially on the hill slopes. Then soil erosion occurs. Only the 20% of the soil in the valleys remains healthy, and 80% of the land is depleted. Because the land is depleted, they need chemical fertilizers and pesticides. United States, Europe, even in Japan, their agriculture started by tilling the land. Cultivation is also related to civilization, and that is the beginning of the mistake. True natural farming uses no cultivation, no plow. Using tractors and tools destroys the true nature. Trees' biggest enemies are the saw and ax. Soil's biggest enemies are cultivation and plowing. If people don't have those tools, it will be a better life for everything.

Since my farm uses no cultivation, no fertilizer, no chemicals, there are many insects and animals living there within the farm. They use pesticide to kill a certain kind of pest, and that destroys the balance of nature. If we allow it to be completely free, a perfect nature will come back.

Robert: How have you applied your method to the deserts?

Masanobu: Chemical agriculture can't change the desert. Even if they have a tractor and a big irrigation system, they are not able to do it. I came to the realization that to make the desert green requires natural farming. The method is very simple. You just need to sow seeds in the desert. Here is a picture of experimentation in Ethiopia. This area was beautiful 90 years ago, and now it looks like the desert in Colorado. I gave seeds for 100 varieties of plants to people in Ethiopia and Somalia. Children planted seeds, and watered them for three days. Because of high temperature and not having water, the root goes down quickly. Now the large Daikon radishes are growing there. People think there isn't any water in the desert, but even in Somalia and Ethiopia, they have a big river. It is not that they do not have water; the water just stays underneath the earth. They find the water under 6 to 12 feet.

Diane: Do you just use water to germinate the seeds, and then the plants are on their own?

Masanobu: They still need water, like after ten days and after a month, but you should not water too much, so that the root grows deep. People have home gardens in Somalia these days.

The project started with the help of UNESCO with a large amount of money, but there are only a couple of people doing the experiment right now. These young people from Tokyo don't know much about farming. I think it is better to send seeds to people in Somalia and Ethiopia, rather than sending milk and flour, but there isn't any way to send them. People in Ethiopia and Somalia can sow seeds, even children can do that. But the African governments, the United States, Italy, France, they don't send seeds, they only send immediate food and clothing. The African government is discouraging home gardens and small farming. During the last 100 years, garden seed has become scarce.

Diane: Why do these governments do this?

Masanobu: The African governments and the United States government want people to grow coffee, tea, cotton, peanuts, sugar - only five or six varieties to export and make money. Vegetables are just food, they don't bring in any money. They say they will provide corn and grain, so people don't have to grow their own vegetables.

Robert: Do we, in the United States, have the type of seeds that would grow well in these parts of Africa?

Masanobu: As a matter of fact, I saw quite a few plants including vegetables, ornamentals, and grains here in this town (Port Townsend) this morning that would grow in the desert. Something like Daikon radish even grows better over there than in my fields, and also things like amaranth and succulents grow very well.

Robert: So if people in the United States and Japan and Europe wanted to help the people in Africa and reduce the desert, would you suggest that they send seeds?

Masanobu: When I was in Somalia, I thought, if there are ten farmers, one truck, and seeds, then it would be so easy to help the people there. They don't have any greens for half of the year, they don't have any vitamins, and so of course they get sick. They have even forgotten how to eat vegetables. They just eat the leaves and not the edible root portion.

I went to the Olympic National Park yesterday. I was very amazed and I almost cried. There, the soil was alive! The mountain looked like the bed of God. The forest seems alive, something you don't find even in Europe. The redwoods in California and the French meadows are beautiful, but this is the best! People who live around here have water and firewood and trees. This is like a garden of Eden. If people are truly happy, this place is a real Utopia.

The people in the deserts have only a cup and a knife and a pot. Some families don't even have a knife, so they have to throw rocks to cut the wood, and they have to carry that for a mile or more. I was very impressed by seeing this beautiful area, but at the same time my heart aches because of thinking about the people in the desert. The difference is like heaven and hell. I think the world is coming to a very dangerous point. The United States has the power to destroy the world but also to help the world. I wonder if people in this country realize that the United States is helping the people in Somalia but also killing them. Making them grow coffee, sugar and giving them food. The Japanese government is the same way. It gives them clothes, and the Italian government gives them macaroni. The United States is trying to make them bread eaters. The people in Ethiopia cook rice, barley and vegetables. They are happy being small farmers. The United States government is telling them to work, work, like slaves on a big farm, growing coffee. The United States is telling them that they can make money and be happy that way.

A Japanese college professor that went to Somalia and Ethiopia said this is the hell of the world. I said, 'No, this is the entrance to heaven.' Those people have no money, no food, but they are very happy. The reason they are very happy is that they don't have schools or teachers. They are happy carrying water, happy cutting the wood. It is not a hard thing for them to do; they truly enjoy doing that. Between noon and three it is very hot, but other than that, there is a breeze, and there are not flies or mosquitoes.

One thing the people of the United States can do instead of going to outer space is to sow seeds from the space shuttle into the deserts. There are many seed companies related to multi-national corporations. They could sow seeds from airplanes.

Diane: If seeds were thrown out like that, would the rains be enough to germinate them?

Masanobu: No, that is not enough, so I would sow coated seeds so they wouldn't dry out or get eaten by animals. There are probably different ways to coat the seeds. You can use soil, but you have to make that stick, or you can use calcium.

My farm has everything: fruit trees, vegetables, acacia. Like my fields, you need to mix everything and sow at the same time. I took about 100 varieties of grafted trees there, two of each, and almost all of them, about 80%, are growing there now. The reason I am saying to use an airplane is because, if you are just testing you use only a small area. But we need to make a large area green quickly. It needs to be done at once! You have to mix vegetables and trees; that's the fastest way for success.

Another reason I am saying you have to use airplanes is that you have to grow them fast, because if there is 3% less green area around the world, the whole earth is going to die. Because of lack of oxygen, people won't feel happy. You

feel happy in the spring because of the oxygen from the plants. We breathe out carbon dioxide and breathe in oxygen, and the plants do the opposite. Human beings and plants not only have a relationship in eating, but also share air. Therefore, the lack of oxygen in Somalia is not only a problem there, it is also a problem here. Because of the rapid depletion of the land in those parts of Africa, everyone will feel this happening. It is happening very quickly. There is no time to wait. We have to do something now.

People in Ethiopia are happy with wind and light, fire and water. Why do people need more? Our task is to practice farming the way God does. That could be the way to start saving this world.

CHAPTER TWENTY-FIVE: OF PRODUCTION ANIMALS: ANIMAL HUSBANDRY

Reference to Chapter 23 on Work Animals

This chapter builds on the lessons of Chapter 23, on Work Animals.

Lessons from working animals can be applied to newly domesticated wild animals for improved production efficiencies

The lessons learned from working animals and wild animals are easily applied to production animals. Wild animals are easily domesticated, and the training methods used for working animals, when applied to the newly domesticated animals, will improved production efficiencies.

Production animals, though they are physiologically different from plants, have similar needs to plants. They are mobile creatures who, if penned too tightly (like plants) will produce at greater expense and suffer from various disease as readily as plants suffer and produce less. The same basic lessons learned by Tull in his vegetables and grains applies to animals as well. The farmer must help the animals eat and provide the animals adequate physical resources, the farmer must care for sick animals, the farmer must undertake conscious evaluation of production to ascertain if efficiency is being maximized. Like plants, they must be fed nutritious food; a thought must be given to the native microorganisms in their guts. The sanitation and hygiene that is typical of Tullian crops must be considered too for animals.

Humane treatment of working, wild and production animals increases profit; production animals best able to provide their own resources

Just as the humane treatment of work animals and wild animals leads to greater profits, so does the humane treatment of production animals. It is especially true with production animals, as they are better than the farmer at providing the resources they require if given the opportunity and the respect and dignity this skill earns pays the farmer back considerably.

Importance of male and female members of each species: a draft animal production agriculture

In this chapter, the importance of both male and female members of each species will be discussed, but the concept, for its novelty, requires introduction. Even in a dairy operation where the male members do not produce milk or eggs, the importance of the male members to the female members of the dairy species should not be underestimated: in most species (humans are an exception), there is a natural division of labor between sexes and female members are simply unable

to be as efficient without their male counterparts – or a farmer to play that role for them. Typically, males will help their females identify and obtain food, water and shelter resources, keep them eating and drinking, comfort them with a sense of security (which allows greater consumption of food and subsequent production), actually defend them against predators, and otherwise tend them as a human herdsman would. Needless to say, the male members of the dairy species does the work as well or better as any human herdsman might for less cost, and can easily be trained (as any work animal) to obey even complex commands such as "round up the cows!" or "bring all the chickens to the coop!"

Such trained working males are not, in fact, production animals per se – they are working animals, and work as hard or harder than any ox or draft horse. However, we will treat of them here because of their intricate relationship to production, reminding the reader to reference training techniques in the working animal chapter.

As Tull has brought vineyard culture to crops, we now bring draft animal husbandry to animal production: the same care and consideration bestowed upon a young ox, if applied to a young chicken, goose, goat or dairy cow will overcompensate the labor and result in long-term efficiencies.

Caution to consult veterinarians

As we urged farmers to consult with veterinarians for their work animals, we urge them to consult with veterinarians for their domestic ones as well: the science of the veterinary medicines is rapidly changing and advancing, and it is important to provide to your animals the most advanced care possible.

Feed and shelter costs motivate free ranges

Feed and shelter costs are the motivating factor behind free ranging animals. The temptation to never need to feed an animal again, or to reduce feed costs to nearly nothing by employing only supplementary feed is very great. Yet to make a free range system work, the farmer must understand how much nutrition their animals are obtaining from the pasture, calculate what deficiencies may be present and supplement with foods that fulfill any deficiency in the diet at the most affordable cost.

To avoid this difficult work, some farmers simply provide free-feeding systems, where animals are "trusted" to prefer grazing and eat only what they do not obtain from pasture. While this works fine with birds who are intelligent enough to know when to stop eating, cattle, goats, sheep and other animals are simply not to be trusted with this system. Thus, it is more common for a farmer to provide some or most of the nutritional requirements of their animals and trust their animals to obtain the rest free range.

Of course, if the farmer were to pen their animals the calculations would be easy and the farmer would not have to be concerned their animals are possibly malnourished, but then the costs of feed are higher.

All feeds imperfect, use a varied diet

It is important to remember that all feeds and pastures may have some deficiencies, but if these deficiencies are small, the likelihood of disease resulting from them is minimal. A combination

of feed and pasture is best, and a combination of feeds is best to overcome whatever imperfections may exist within the diet.

NUTRIENT REQUIREMENTS OF ANIMALS AND NUTRIENT VALUES OF SOME FEEDS

Values represent the concentration of nutrients per kilogram, not total daily value, except when noted.

Starred (*) Values indicate the true requirements for these nutrients have not been defined, pending further studies.

SOURCES:

- *Joint United States-Canadian tables of feed composition:* National Research Council (U.S.). Committee on Animal Nutrition, National Committee on Animal Nutrition (1964)
- *Nutrient Requirements of Poultry, Ninth Revised Edition:* the National Academy Of Sciences
- *Nutrient Requirements of Dairy Cattle, Seventh Revised Edition:* the National Academy Of Sciences
- *Nutrient Requirements of Horses, Sixth Revised Edition:* the National Academy Of Sciences
- *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids:* the National Academy Of Sciences
- *Onobrychis viciifolia Scop:* Dr. John Frame, United Nations Food and Agriculture Organization. *http://www.fao.org/ag/AGP/agpc/doc/gbase/data/Pf000347.htm*
- *Perennial Ryegrass (Lolium perenne L.) PNW 502:* D. Hannaway, S. Fransen, J. Cropper, M. Teel, M Chaney, T. Griggs, R. Halse, J. Hart, P. Cheeke, D Hansen, R. Klinger, and W. Lane, Oregon State University Extension Service, 1999 (http://extension.oregonstate.edu/catalog/html/pnw/pnw503/)
- *2009 Feed Composition Tables (http://www.scribd.com/ doc/21334311/Animal-Feed-Composition-Tables-2009):* Scribd.com
- *USDA National Nutrient Database of the USDA Nutrient Data Laboratory, http://www.nal.usda.gov/fnic/foodcomp/search/* USDA
- *Work Horse Handbook:* Lynn R Miller (1981).

Nutrient Requirements for Layer Chickens

	0-6wks	6-12wks	12-18wks	18wk-1st egg	Adult Hen	Adult Rooster
Macronutrients						
Calories (kcal/kg)						
Calories (kcal/day)	20-143	143-171	171-207	207-227	192-408	130-296
Crude Protein	17-18%*	15-16%*	14-15%*	16-17%*	12.5-18.8%*	12.5-18.8%
Fat	1%	1%	1%	1%	0.83-1.25%	0.83-1.25%
Crude Fiber	*	*	*	*	*	*
ADF	*	*	*	*	*	*
NDF	*	*	*	*	*	*
Minerals						
Calcium	0.90%	0.80%	0.80%	1.8-2%	2.71-4.06%	*
Phosphorus	0.40%	0.35%	0.30%	0.32-0.35%	0.21-0.31%	*
Iron, mg	75-80	56-60	56-60	56-60	38-56	*
Zinc, mg	38-40	33-35	33-35	33-35	29-44	*
Magnesium, mg	570-600	470-500	370-400	370-400	420-625	*
Manganese, mg	56-60	28-30	28-30	28-30	17-25	*
Copper, mg	5	4	4	4	*	*
Selenium, mg	0.14-0.15	0.1	0.1	0.1	0.05-0.08	*
Potassium	0.25%	0.25%	0.25%	0.25%	0.13-0.19%	*
Cobalt, mg	*	*	*	*	*	*
Vitamins						
Vitamin A, IU	1420-1500	1420-1500	1420-1500	1420-1500	2500-3750	*
Vitamin E, IU	9.5-10	4.7-5	4.7-5	4.7-5	4.6	*

Nutrient Requirements for Waterfowl

		Geese: 0-4wks	Geese: 4wks-full grown	Geese: breeding	Ducks: 0-2wks	Ducks: 2-7wks	Ducks: breeding
Macronutrients							
	Calories (kcal/kg)						
	Calories (kcal/day)	174-580	638-660	*	91-302	302-675	*
	Crude Protein	0.2	0.15	0.15	0.22	0.16	0.15
	Fat	*	*	*	*	*	*
	Crude Fiber	*	*	*	*	*	*
	ADF	*	*	*	*	*	*
	NDF	*	*	*	*	*	*
Minerals							
	Calcium	0.65%	0.60%	2.25%	0.0065	0.006	0.0275
	Phosphorus	0.30%	0.30%	0.30%	0.004	0.003	*
	Iron, mg	*	*	*	*	*	*
	Zinc, mg	*	*	*	60	*	*
	Magnesium, mg	*	*	*	500	500	500
	Manganese, mg	*	*	*	50	*	*
	Copper, mg	*	*	*	*	*	*
	Selenium, mg	*	*	*	0.2	*	*
	Potassium	*	*	*	*	*	*
	Cobalt, mg	*	*	*	*	*	*
Vitamins							
	Vitamin A, IU	1500	1500	4000	2500	2500	4000
	Vitamin E, IU	*	*	*	10	10.0	10

Nutrient Requirements for Turkeys

		0-4wks	4-8wks	8-15wks	15wks - full grown	Adult: non-laying	Adult: laying hens
Macronutrients							
	Calories (kcal/kg)						
	Calories (kcal/day)	40-285	285-714	714-1657	1657-2485	750-1827	754-928
	Crude Protein	0.28	0.26	19-22%	14-16.5%	0.12	0.14
	Fat	1%	1%	1%	1%	0.008	0.011
	Crude Fiber	*	*	*	*	*	*
	ADF	*	*	*	*	*	*
	NDF	*	*	*	*	*	*
Minerals							
	Calcium	1.20%	1.00%	0.75-0.85%	0.55-0.65%	0.005	0.0225
	Phosphorus	0.60%	0.50%	0.38-0.42%	0.28-0.32%	0.0025	0.0035
	Iron, mg	80	60	60	50	50	60
	Zinc, mg	70	65	40-50	40	40	65
	Magnesium, mg	500	500	500	500	500	500
	Manganese, mg	60	60	60	60	60	60
	Copper, mg	8	8	6	6	6	8
	Selenium, mg	0.2	0.2	0.2	0.2	0.2	0.2
	Potassium	0.70%	0.60%	0.50%	0.40%	0.004	0.006
	Cobalt, mg	*	*	*	*	*	*
Vitamins							
	Vitamin A, IU	5000	5000	5000	5000	5000	5000
	Vitamin E, IU	12	12	10	10	10.0	25

Nutrient Requirements for Dairy Cattle

	Calf: unweaned	Calf: weaned	Dry Heifer	Late Gestation Cow	Lactating Cow (large breed)	Lactating Cow (small breed)
Macronutrients						
Calories (kcal/kg)						
Calories (kcal/day)	1430-5520	2580-8590	6000-17400	15700-26100	20790-48300	27700-39500
Crude Protein	8-24%	7-15%	10-12%	10.2-12.8%	15.5-22.4%	16-24%
Fat	*	1%	*	*	*	*
Crude Fiber	*	*	*	*		
ADF	*	*	*	17-22% min	17-21% min	17-21% min
NDF	*	*	*	25-38% min	25-33% min	25-33% min
Minerals						
Calcium	0.7-1.0%	0.60%	0.40%	0.45-0.98%	0.60-0.67%	0.54-0.66%
Phosphorus	0.45-0.76%	0.40%	0.21%	0.23-0.4%	0.32-0.38%	0.33-0.44%
Iron, mg	50-100	50	*	13	12.3-18	14-18
Zinc, mg	15-40	40	*	22	43-55	45-54
Magnesium, mg	0.07-0.10%	0.001	*	0.12-0.40%	0.18-0.21%	0.18-0.21%
Manganese, mg	40	40	*	18	13-14	12
Copper, mg	10	10	*	13	11	11
Selenium, mg	0.3	0.3	*	0.3	0.3	0.3
Potassium	0.65%	0.65%	*	0.52-1.32%	1.00-1.07%	1.02-1.07%
Cobalt, mg	0.10-0.11%	0.10%	*	11.00%	11.00%	0.11
Vitamins						
Vitamin A, IU	4000-9000	4000	*	6030-7300	2500-3685	2520-2770
Vitamin E, IU	25-50	25	*	88-132	18-27	16-20

Nutrient Requirements of Draft Oxen or Beef Cattle

	Growing: BW 200kg, ADG 1.5kg/day	Growing: BW 450kg, ADG 1.5kg/day	Dry Heifer	Late Gestation Cow	Lactating Cow	Bull
Macronutrients						
Calories (kcal/kg)						
Calories (kcal/day)	4240	7790	8310	9900-18203	27700-39500	6380-13320
Crude Protein	0.063	0.0352	0.0415	0.0718	16-24%	0.0572
Fat	*	*	*	*	*	*
Crude Fiber	*	*	*	*	*	*
ADF	*	*	*	*	*	*
NDF	*	*	*	*	*	*
Minerals						
Calcium	0.56%	0.25%	0.19%	0.003	0.54-0.66%	0.0025
Phosphorus	0.23%	0.10%	0.12%	0.003	0.33-0.44%	0.0019
Iron, mg	*	*	*	*	*	*
Zinc, mg	*	*	*	*	*	*
Magnesium, mg	*	*	*	*	*	*
Manganese, mg	*	*	*	*	*	*
Copper, mg	*	*	*	*	*	*
Selenium, mg	*	*	*	*	*	*
Potassium	*	*	*	*	*	*
Cobalt, mg	*	*	*	*	*	*
Vitamins						
Vitamin A, IU	*	*	*	*	*	*
Vitamin E, IU	*	*	*	*	*	*

Nutrient Requirements of Horses

	Weanling (4-6 months)	Yearling (12-18 months)	Late Gestation Mare	Lactating Mare	Adult (Maintenance)	Adult (Moderate Work)
Macronutrients						
Calories (kcal/kg)						
Calories (kcal/day)	12500-13000	16500-17250	17600-19200	22000-27600	16000	22800
Crude Protein	13..0-13.1%	10.8-11.3%	8.9-9.5%	10-12%	0.072	0.094
Fat	*	*	*	*	*	*
Crude Fiber	*	*	*	*	*	*
ADF	*	*	*	*	*	*
NDF	*	*	*	*	*	*
Minerals						
Calcium	0.5-0.62%	0.32-0.39%	0.39-0.41%	0.33-0.47%	0.0021	0.0028
Phosphorus	0.28-0.34%	0.18-0.21%	0.30%	0.2-0.3%	0.0015	0.002
Iron, mg	*	*	*	*	*	*
Zinc, mg	*	*	*	*	*	*
Magnesium, mg	*	*	*	*	*	*
Manganese, mg	*	*	*	*	*	*
Copper, mg	*	*	*	*	*	*
Selenium, mg	*	*	*	*	*	*
Potassium	*	*	*	*	*	*
Cobalt, mg	*	*	*	*	*	*
Vitamins						
Vitamin A, IU	1430-1672	1958-2046	3278-3322	2486-2728	1650	2134
Vitamin E, IU	*	*	*	*	*	*

Calculated based on 500lb weanling body weight, 750lb yearling body weight, and 1000 lb adult body weight. Heavy work not demonstrated because draft animals should not be worked heavily but only upon exceptional emergency circumstances. Moderate work, in this example is equivalent to a ½ day of normal farm work (4 hours). Those who would work their horses longer should increase feed and adequately condition the horses to the long work hours and required physical endurance.

Nutrient Requirements of Goats							
		Growing (BW 45 lb)	Growing (BW 90 lb)	Adult ‡ (Maintenance)	Late Gestation Doe‡	Lactating Doe‡ at 4%milk fat	Adult ‡, Mohair production
Macronutrients							
	Calories (kcal/kg)						
	Calories (kcal/day)	937.3	1301.3	1510	2301.7	2195	1560
	Crude Protein	0.0748	0.0781	0.0754	0.0866	0.0769	0.0756
	Fat	*	*	*	*	*	*
	Crude Fiber	*	*	*	*	*	*
	ADF	*	*	*	*	*	*
	NDF	*	*	*	*	*	*
Minerals							
	Calcium	0.20%	0.24%	0.29%	0.0029	0.00293	0.00289
	Phosphorus	0.14%	0.17%	0.19%	0.00189	0.0019	0.00187
	Iron, mg	*	*	*	*	*	*
	Zinc, mg	*	*	*	*	*	*
	Magnesium, mg	*	*	*	*	*	*
	Manganese, mg	*	*	*	*	*	*
	Copper, mg	*	*	*	*	*	*
	Selenium, mg	*	*	*	*	*	*
	Potassium	*	*	*	*	*	*
	Cobalt, mg	*	*	*	*	*	*
Vitamins							
	Vitamin A, IU	1452	1452	1452	2178	8360	1452
	Vitamin E, IU	299.2	299.2	299.2	299.2	1672.0	292.6

‡ Values are for adults weighing 176lbs

Nutrient Content of Animal & Human Food - I

Grains and Beans

	Barley (Hulled)	Pinto Beans	Soy Beans	Yellow Indian Corn	Flax - must be ground to digest	Oats	Rye	Split Peas	Safflower
Macronutrients									
Calories (kcal/kg)	354	347	446	365	534	389	338	341	517
Moisture	9.44%	11.33%	8.54%	10.37%	6.96%	8.22%	10.60%	11.27%	5.62%
Crude Protein	12.5%	21.4%	36.5%	9.4%	18.3%	16.9%	10.3%	24.6%	16.2%
Fat	2.3%	1.2%	19.9%	4.7%	42.2%	6.9%	1.6%	1.2%	38.5%
Crude Fiber	17.30%	15.50%	9.30%	7.30%	27.30%	10.60%	15.10%	25.50%	*
ADF	*	*	*	*	*	*	*	*	*
NDF	*	*	*	*	*	*	*	*	*
Minerals									
Calcium	0.03%	0.11%	0.28%	0.01%	0.26%	0.05%	0.02%	0.06%	0.08%
Phosphorus	0.26%	0.41%	0.70%	0.21%	0.64%	0.52%	0.33%	0.37%	0.64%
Iron	0.0036%	0.0051%	0.0157%	0.0027%	0.0057%	0.0047%	0.0026%	0.0043%	0.0049%
Zinc	0.0028%	0.0023%	0.0049%	0.0022%	0.0043%	0.0040%	0.0027%	0.0030%	0.0051%
Magnesium	0.13%	0.18%	0.28%	0.13%	0.39%	0.18%	0.11%	0.12%	0.35%
Manganese	0.0019%	0.0012%	0.0025%	0.0005%	0.0025%	0.0049%	0.0026%	0.0014%	0.0020%
Copper	0.0005%	0.0009%	0.0017%	0.0003%	0.0012%	0.0006%	0.0004%	0.0009%	0.0018%
Selenium	0.0038%	0.0028%	0.0178%	0.0016%	0.0254%	*	0.0014%	0.0002%	*
Potassium	0.45%	1.39%	1.80%	0.29%	0.81%	0.43%	0.51%	0.98%	0.69%
Cobalt	*	*	*	*	*	*	*	*	*
Sulfur	0.1500%	*	*	0.1200%	*	0.2100%	*	*	*
Vitamins									
Vitamin A, IU	22.00	*	22.00	214.00	*	*	11.00	149.00	50.00
Vitamin E, IU	0.86	0.32	1.28	0.74	0.47	*		0.14	*

Notes: Flax must be ground into flour for digestion! The hulls are so hard they are used, when unground, similar to gravel in the gizzards of birds.

Nutrient Content of Animal & Human Food - II									
	Grains and Beans			*Vegetables*			*Hay*		
	Sanfoin Seed	Sun-flower Seeds	Red Spring Wheat	Spirulina Seaweed	Pumpkin Squash	Turnips	Alfalfa Hay	Timothy / Orchard Grass	Sanfoin Hay
Macronutrients									
Calories (kcal/kg)	369.2	584	329	290	26	28	430.9	395.6	683.4
Moisture	8.20%	4.73%	12.76%	4.68%	91.60%	91.87%	0.00%	0.00%	0.00%
Crude Protein	27.6%	20.8%	15.4%	57.5%	1.0%	0.9%	17.5%	8.5%	14.0%
Fat	5.2%	51.5%	1.9%	0.0%	0.1%	0.1%	1.8%	2.7%	*
Crude Fiber	17.10%	8.60%	12.20%	*	0.50%	1.80%	30.00%	34.00%	24.00%
ADF	22.9%	*	*	*	*	*	36.0%	39.0%	37.0%
NDF	30.1%	*	*	*	*	*	47.0%	63.0%	50.8%
Minerals									
Calcium	0.33%	0.08%	0.62%	0.12%	0.02%	0.03%	1.20%	0.40%	1.57%
Phosphorus	0.65%	0.66%	0.04%	0.12%	0.04%	0.03%	0.28%	0.28%	0.28%
Iron	0.0177%	0.0053%	0.0360%	0.0285%	0.0008%	0.0003%	0.0250%	*	0.0174%
Zinc	0.0061%	0.0050%	0.0200%	0.0020%	0.0003%	0.0003%	*	*	0.0038%
Magnesium	0.21%	0.33%	0.32%	0.20%	0.01%	0.01%	0.2900%	*	0.2000%
Manganese	0.0064%	0.0020%	0.0041%	0.0019%	0.0001%	0.0001%	0.0045%	*	0.0056%
Copper	0.0025%	0.0018%	0.0004%	0.0061%	0.0001%	0.0001%	0.0008%	*	0.0012%
Selenium	*	0.0005%	0.0071%	0.0007%	0.0000%	0.0007%	*	*	0.2400%
Potassium	0.26%	0.65%	0.34%	1.36%	0.34%	0.19%	2.0100%	*	1.9700%
Cobalt	*	*	*	*	*	*	*	*	0.0000%
Sulfur	0.1700%	*	*	*	*	*	0.1300%	*	0.2400%
Vitamins									
Vitamin A, IU	*	*	9.00	570.00	7384.00	0.00	0.45	*	*
Vitamin E, IU	50.00	35.17	1.30	5.00	1.59	0.05	*	*	*

Other charts from previous chapters

	Ryegrass
Macronutrients	
Calories (kcal/kg)	246.9
Moisture	0.00%
Crude Protein	19.0%
Fat	*
Crude Fiber	32.60%
ADF	25.2%
NDF	45.5%
Minerals	
Calcium	0.62%
Phosphorus	0.41%
Iron	*
Zinc	*
Magnesium	0.32%
Manganese	*
Copper	*
Selenium	*
Potassium	1.99%
Cobalt	*
Sulfur	*
Vitamins	
Vitamin A, IU	*
Vitamin E, IU	*

Macronutrients	Hard Red Spring	Hard Red Winter	Soft Red Winter
Calories (kcal/kg)	329	327	331
Moisture	12.76%	13.10%	12.17%
Crude Protein	15.4%	12.6%	10.4%
Fat	1.9%	1.5%	1.6%
Crude Fiber	12.20%	12.20%	12.50%
ADF	*	*	*
NDF	*	*	*
Minerals			
Calcium	0.62%	0.29%	0.27%
Phosphorus	0.04%	0.03%	0.03%
Iron	0.0360%	0.0390%	0.0321%
Zinc	0.0200%	0.0265%	0.0263%
Magnesium	0.32%	0.13%	0.13%
Manganese	0.0041%	0.0040%	0.0044%
Copper	0.0004%	0.0004%	0.0005%
Selenium	0.0071%	0.0071%	*
Potassium	0.34%	0.19%	0.40%
Cobalt	*	*	*
Sulfur	*	*	*
Vitamins			
Vitamin A, IU	9.00	9.00	*
Vitamin E, IU	1.30	1.30	1.30

Encouraging growth, preventing and curing illness with special nutrition: a recipe for Fortified Water – suitable for all animals and people

While some farmers will feed their animals fortified water to prevent illness and encourage growth, others will employ it only when the animals are ill. Regardless of whether it is usually used, fortified water is an excellent food for sick or injured animals (or people) and will be discussed first because it demonstrates the supporting philosophy of husbandry.

The origin of fortified water for people is found in the drink Gatorade. Gatorade (named after the Florida Gators – the athletic teams of the University of Florida) was developed to help (aid) the Gators (athletes) replenish necessary nutrients during the extreme physical activity of playing sports in the hot Florida sun. This gave the Gators an advantage over their competitors who, by the end of the match, were depleted and exhausted.

Naturally, the development was adopted by farmers who sought to aid their animals replenish those nutrients lost or used during the heavy work of production. Just as palatability issues dogged the first batches of Gatorade until some lemon was added to the water, palatability may be an issue for animals, as well.

As a broken bone is supported by a splint or cast so that the body can heal it properly, the farmer's job is to support a sick, injured or healthy animal. By providing the energy and nutrition the body requires, the caretaker can aid the body in undertaking its defense and repair: this way, defense and repair will not be interrupted for lack of nutrition or energy!

In this way, even chemical poisoning can be detoxified from an animal and the caretaker can assist the animal in healing from severe wounds: the caretaker is able to help the animal help itself. However, in all cases of injury and sickness, a veterinarian ought to be consulted.

Prepare a mixture of: 6 ounces water and 2 ounces sugar or 4 ounces fruit juice (to taste – some animals or people will prefer all fruit juice and no water).

To this add soluble balanced protein powder and vitamin and mineral powder (which can be either bought from animal feed suppliers, or made by grinding up human protein, vitamin and mineral supplement tablets, or by grinding up fortified breakfast cereals and breads). The amount to add will vary depending on the product used for fortification, and may require additional water for dissolving, or sugar for palatability. Ensure that the animal is obtaining at least 100% of their daily requirements for vitamins, minerals and protein, an excess of nutrition is not a problem in most cases. Salt is an essential mineral and should not be neglected, either.

Optional: provide flavoring to make it more palatable.

Some animals produce vitamins that humans do not, and what is essential for a human is not necessarily so for another animal. Consulting the nutritional requirement tables previously inserted to this chapter will help the farmer understand what is required.

It bears mentioning here that sometimes the animal will require additional support for injury. Good diet, especially a supplemented one, encourages quick healing and return to productivity. But, injuries require medical attention, bandages, heat, cold or other non-dietary treatments.

The best preventative medicine to undertake against disease and injury is good diet. A varied diet of many kinds of foods, whether it is a grain mixture or grain supplement with pasture, allows for better health than a diet of a single kind of food.

All birds earn similar profit

Just as many kinds of crop productions earn about the same profit per acre, all birds (and most animals) earn similar profit as well.

To make a comparison between birds in terms of their egg laying efficiency is possible, but not necessarily useful to the farmer. The data, gathered from the *Nutrient Requirements of Poultry, Ninth Revised Edition* (the National Academy Of Sciences), the Nutrient Data Laboratory of the USDA (http://www.nal.usda.gov/fnic/foodcomp/search/) and Dave Holderread's *The Book of Geese, a Complete Guide to Raising the Home Flock* (1981), allows some insight into the reasons why some species are raised for their eggs and others are not, not directly from its data, but by comparing its data against real market conditions.

The data we combined had some variability, but values were averaged across reports and were not significant when they did, rarely, vary.

Species (and Breed)	Egg Weight per Dozen (pounds)	Annual Egg Production (number)	Annual Egg Production (pounds)	Annual Feed Consumption Free Range (pounds)	Annual Feed Consumption Confined (pounds)	Feed to Yield 1 pound Eggs - Free Range	Feed to Yield 1 pound Eggs - Confined	Years of Peak Efficiency
Duck (Campbell)	1.85	288	46.5	110	140	2.37	3.01	2 - 3
Chicken (Leghorn)	1.56	240	30	85	95	2.83	3.17	1 - 2
Goose (China)	3.80	72	24.8	130	185	5.24	7.46	4 - 8
Guinea Fowl	1.06	78	6.9	45	65	6.52	9.42	1 - 2
Turkey (Lg.White)	2.04	90	17.8	180	200	10.11	11.24	1 - 2
Quail (Coturnix)	0.24	306	8.8	ND	22	ND	2.50	1

Species (and Breed)	Egg Protein (%)	Egg Fat (%)	Egg Ash (%)	Egg Cholesterol (%)	Calories (per 100 g)	1 lb feed produces lbs fat	1 lb feed produces lbs protein	1 lb feed produces (#) eggs	1 lb feed produces (#) calories
Duck (Campbell)	12.81%	13.77%	1.14%	0.88%	185	0.015	0.014	0.106	4.34
Chicken (Leghorn)	12.57%	9.94%	0.86%	0.42%	143	0.015	0.019	0.151	4.77
Goose (China)	13.87%	13.27%	1.08%	0.85%	185	0.015	0.016	0.115	4.68
Guinea Fowl	ND	ND	ND	ND	ND	ND	ND	0.512	ND
Turkey (Lg.White)	13.68%	11.88%	0.79%	0.93%	171	0.049	0.057	0.413	15.57
Quail (Coturnix)	13.05%	11.09%	1.10%	0.84%	158	ND	ND	ND	ND

Of course, free range birds need not be fed at all, if their pasture is sufficient, but this represents a habit of supplementing pasture. We had a neighbor who once raised turkeys for eggs and did not supplement them at all: he was satisfied with the low production of his turkeys because he estimated that the cost of feeding them would not have been overcompensated by the increase in egg production.

Feed may cost more or less depending on what kind of feeds are used: some are more nutritionally sound than others and it is sometimes possible to reduce the amount of feed by 25% or more by calculating feed costs against nutritional needs.

If the farmer were to only be seeking to maximize feed efficiency, there would be more duck eggs on the market than chicken eggs; if the farmer sought to maximize the feed to calorie or protein

or fat ratio, there would be more turkey eggs on the market than chicken eggs. But this is not the case: there are many more chicken eggs available than duck or turkey eggs.

Why does the market demand chicken eggs? Certainly not to minimize cholesterol, despite the recent medical concerns for cholesterol: cholesterol is difficult to taste, and consumers developed a preference for chicken eggs long before a popular understanding of the potential for too much cholesterol in the diet ever existed.

Consumers are better driven by price.

Chickens are not cheaper to feed, but they are cheaper to house and otherwise are more cost-efficient than their feed-efficient cousins. Not in terms of feed, but in terms of housing. Geese are more cost-efficient than ducks (which rely on water even more, their noses are located far up on the head in contrast to the grazing geese whose nose is located on the beak) because they are at home in the water and on land.

Yet do not underestimate the preferences of taste and cultural norms. Consumer preferences and habits change over time: in ancient Rome, pigeon eggs were preferred over chicken eggs because the chicken was a sacred animal and, as old religions faded to old superstitions and those old superstitions gave way, chicken eggs became more popular because they tasted better to the Romans. In Japan, Masanobu Fukuoka, who also raises ducks for eggs, finds that his countrymen, who until their loss in the Second World War, appreciated duck eggs better than the chicken eggs of the Americans, are again open to buying duck eggs. But, that said, the Japanese will have to pay more for duck eggs because they are not as cheap to produce.

The lower costs associated with chickens translates out to a lower price at the market; the duck egg earns more because it costs more. Like the plant farmer, the animal farmer often finds they will earn the same amount across species. No one species is more suited for free range production than another, except when considering local environmental pressures.

Caged, penned, free range and the need for supplemental diets and shelter, comparative mortality rates

Caged is a term to describe an animal whose movement is almost entirely restricted. *Penned* describes an animal whose movements are unrestricted but whose migration patterns for foraging, shelter-finding and other resource acquisition is restricted – even if the animal is restrained on 20 acres and it would normally roam 21 acres, it is a penned animal. An animal that is penned on 20 acres and would normally roam 1 acre or even 19 acres is not penned, but is free ranged. *Free Range* describes an animal whose movement and migration is unrestricted: no fences, no walls, nothing prevents the animal from going where it wants to go in its search for resources.

Animals who are free range are less costly than those which are caged or penned. Besides the cost of installing and upkeeping the cage or pen, the animals are able to feed themselves on what pastures they find (which may or may not be improved or supplemented by the farmer), they are healthier because their daily movement is so important to their health. They are healthier because free range animals can never suffer the indignity and inconvenience of unsanitary conditions as penned or caged animals might: when filth becomes too great to bear, the animals may avoid it.

Even when the farmer supplements the feed of their animals with food, the bird farmer (using the data from previous tables) still saves more than 21% on feed costs on average (while still producing the same number of eggs!).

The principle of supplementation works on the premise that the animal needs a certain amount of low quality food to digest higher quality foods: this "bulk" is usually provided for by way

of hay or straw in cages (either integrated into the higher quality food by way of pelletization, or fed separately). Even humans need this "bulk" in their diet; without enough dietary fiber, humans cannot ingest their food, their intestines become diseased and eventually toxemia may result.

For the free ranging farmer, nature provides these low quality foods – and quite a few higher quality foodstuffs too! Most animals need to eat regularly for physical and mental health, and the farmer who lets them find pasture does not need to provide for this: the happier, less bored animal gains weight better and produces more at less cost than the caged, bored animal ever could.

Additionally, caged and penned animals do not have as wide of a selection of foods to eat, and may suffer dietary deficiencies, but free ranged animals do not: they can choose among the foods they need to eat and can seek out what they do not have.

Some farmers pen their animals and say that they are free range, but there is nothing the consumer can do against these lies except examine the production facilities.

Cages cost more than pens because cages require extensive environmental controls: waste air, liquids and solids must be removed, fresh air, liquids and solids must be brought in, temperature must be maintained, light must be provided for and regulated, etc. Pens cost more than free ranges for similar reasons: though less environmental control is required, wastes must still be managed, fresh resources must be brought in. Farmers who pen animals try not to overstock their pasture so that the amount of management is minimal or non-existent, but these farmers must still establish and maintain fences or other barriers to migration.

Caging and penning birds results in higher costs with little or no increase in production, less healthy animals and lower quality product. Free ranging animals, while supplementing their diet and providing quality housing, is an ideal production method.

Masanobu Fukuoka was a proponent of free ranging animals, and earned good profits on his ducks. His customers – as ours did and yours will too – noticed that the eggs tasted better. Animals who are free range have a varied and balanced diet, and their production is of higher quality.

Fukuoka did not even provide the ducks a shelter, but let them make their nests wherever they wanted on his land. While finding the nests for him was a fun chore, we recommend a coop, kennel or barn system that the animals can enter and leave freely because the minimal expense of the shelter greatly improves the health and quality of life for the animals. We will close the door on our chicken coops while the birds sleep at night: this helps them rest easier at night and work harder during the day, and this small act alone reduces bird loss to predators enough to compensate the labor and expense of their coops. Birds naturally seek a shelter in the night, and just as we provide them the best foods, pasture and waters to choose from, we must provide them the best shelter as well!

Some animals, especially cattle, wander all night or do not have periods of sustained rest. Yet they also appreciate coops and barns in bad weather. In experience with geese, we have provided them the option of kennels, coops and no shelter at all, and they prefer coops to kennels and kennels to no shelter at all. They will even come fetch a person to close them in at night when it gets dark!

This said, the farmer will prefer the animals to have a shelter or a pen during harvesting, veterinary checkups and other maintenance times. Collecting eggs all in one place is convenient, having all the animals round themselves up into a pen or coop not only impresses the veterinarian, the milkers, the branders, the shearers and other farm workers, but also makes their work easier and more affordable.

It bears being said again: a good shelter encourages a central deposition of eggs in birds and efficient resource use in all species: it is a central place to deposit food and water, and a central location by which farm work may be done.

Because it is a central location of food and water, the animals will develop a sense of territory based around shelter and food resources. Providing good shelter helps organize territories and allows an even distribution of animals across larger acreages: in example, each flock of chickens (typically less than 500 birds) will wander typically less than 5 acres (at, according to our measurements, about 1 acre per 100 birds), but if more than 1 acre is available for flocks to graze upon, spacing coops (or clusters of coops) 5 acres distant from each other improves land efficiency. Coops can be clustered to increase the density of the flock in that territory. We have found that increased density does not necessarily translate into greater sized territories for a flock, and that territory size depended most upon the individual roosters involved.

Cattle need to use land very efficiently, and encouraging territorialism in the bulls allows several herds to make better use of the space. It may be that the space is large enough to house two herds, and then the herds will combine. Bulls are smart enough to know how much land their cows require.

Some animals will die no matter the management. This is called "mortality." There is little difference between the combined mortality rates for healthy mature animals and immature animals in well managed caged and well managed free range production. A 5% mortality rate per year is expected, though some years we have had as few as 1% mortality, and as great as 99% mortality (and while that year was exceptional and due to criminal vandalism, it goes to show that even with good management, natural or human-caused disaster can strike). When mortality increases above 5% among mature and immature animals, it is a good indicator that something is wrong with the environment of your animals. Mortality rates are, of course, higher among older (post-mature) individuals.

Post-mature ("old") animals are more useful in free range production than in caged production: most importantly, older animals tempt predators more than other age groups and they teach younger animals where resources are and how to access them best. The older animals also teach the younger ones how to obey commands from their master and their work animals. While it is unlikely that predation of the flock or herd will occur, you would rather have an old, unproductive animal be eaten than your most productive cow or hen. You would rather your bull, ram or rooster die defending the production animals than lose your production animals; you want to have several "back-up" working male animals and at least several older animals in the herd or flock.

Sometimes lions will kill for sport and not even eat the animals they attack. We know of a cattle rancher who lost all of his oldest cows before he was able to shoot the lion that was attacking his herd. He lost none of his productive cows, and the older cows died defending the herd. We have seen one of our largest roosters (a big Austrolorp named "Curly") defend his flock against a coyote, beating the animal off with his talons and wings and beak.

Some animals remain productive into old age: most chickens will lay at their peak efficiency within the first 2 years of their life, but older birds will still lay eggs even as they provide those useful services to the flock. In cage systems, birds are removed from production after their peak efficiency has been achieved because laying eggs is the only use they serve. These "culled" animals are sold for meat. In free range systems, the farmer eventually "sells" these older animals to the predators who would have struck more efficient birds and the cost of feeding and housing these older animals is less than the replacement value of the younger, more efficient bird. Roosters, too, will sacrifice themselves for their hens and preserve the egg-laying efficiency of the flock for the farmer.

Why feed human food to animals or use land that could be used to grow human food to feed grow animal feeds? Why eat eggs and milk?

Eggs and milk provide the same nutrition as the grains and other foods used to feed the animals that produce them, and the amount of food fed to the animals could feed many people. There are several reasons why eggs and milk are consumed instead of the animal feed used to grow them.

Animal feeds are typically foods which people cannot eat. While grass is, technically, edible by human beings, allowing a goose to graze the grass and produce an egg that is more nutrient dense than grass (and more palatable) makes sense.

But an argument that the same pasture the goose is dining upon could be used to grow grains to feed people by is valid. There are those who would starve the goose to feed a person.

Yet it cannot be ignored that the density of the nutrition in the egg again is a dominant factor in its consumption and need for it by people: the human stomach can only hold so many pounds and cubic inches of food, and the human gut can only digest so much food per hour. It is in the interests of a hard-working human to eat nutritionally dense food, and while the total pounds and cubic inches of food consumed by a human being will remain the same despite their income, those with more income will spend it to obtain foods that have more nutrition per pound or per cubic inch, justifying the cost of the pasture for the goose. The goose itself – and all animals – will also prefer dense foods, preferring alfalfa hay to grass, and grains or beans to alfalfa hay.

The demand for dense foods is tempered somewhat by a diminishing return to their consumption: a diet of dense foods is unhealthy, and while supplementing dense foods into the diet is useful and beneficial, animals and people will get sick if they eat too many dense foods for several reasons: the quantity of protein consumed on a diet of dense foods is undigested, leading to autointoxication; the quantity of energy consumed on a diet of dense foods leads to sugar in the blood and too many fat stores. There are other problems associated with dense diets, but these are two major concerns for feeding animals or people a diet of dense foods.

There is another reason, but it is not typical: sometimes these foods are used in medicine. Raw milk and raw eggs provide friendly microorganisms to the gut that will help a person overcome autointoxication or other disease. Additionally, the balanced protein source of the milk and the eggs helps prevent and treat malnutrition that came from improper protein balance. Improper protein balance is rare, as nearly any two different kinds of food (grains and beans, for example) provide a balanced protein to the diet.

Supplemental shelter - establishing coops and supporting structures and landscaping

The free range farmer will likely need to provide some supplemental shelter in addition to supplemental feed.

Chickens and geese will require land for their coops, supporting structures and necessary landscaping. While hills are not necessarily bad for their structures, the area should be level where these structures are located to make their construction more sound. Cattle, goats, sheep and other animals also require housing in the form of barns or lean-to's. Do not put the structures in low-lying areas so that what filth may accumulate will wash away, not pool.

Geese, ducks and other water fowl will require the additional improvement of a pond and chickens require a puddle. All animals appreciate a dirt patch for dust baths, and especially enjoy ashes. If the farm uses a firepit or fired oven, consider keeping it convenient to the animal shelters for ash disposal. Ponds are used for drinking, swimming and hygiene; ashes and dust for hygiene alone. Ponds, if there is no puddle, should have a shore from which the chickens (who swim with difficulty) may easily drink. Ponds, in any case, should have an easy slope to the bottom to reduce the risk of drowning for chickens, rodents, or other visitors to the pond: rotting carcasses decrease water quality.

While many authors claim that geese do not like to be housed in coops, we have undertaken trials and discovered that they prefer coops as much as chickens do. That said, both chickens and geese prefer fenced kennels to coops – except in inclement weather!

Geese can be trained, just like chickens, to "go home," whether that home is an enclosed coop (not advised) or a fenced and screened kennel (advised). A screened and fenced kennel keeps them safe from predators at night (the geese are hardy enough to not need windblocks or heat in most temperate areas) and reduces the risks of moisture-fed disease (goose poop is very moist) in the bedding.

Despite what is most hygienic, in trials our geese preferred to sleep in a coop more than in a kennel. Judging by observations, they seemed to prefer its security: they did not need to post a guard over their flock at night in the coop, and their normal sleep pattern of short naps day and night changed so they rested most of the night and were active most of the day.

Some of our geese preferred sleeping in the chicken coop because they formed a bond with the roosters who lived there. We raise chickens and geese together, and they readily bond: one of our chickens was always with the geese and cared nothing for the company of other chickens. It is fortunate that, save for the pond, chickens and geese require nearly the same diet and shelters.

If an earthen pond is impossible because the soil will not support a pond, a hole can be dug and lined with tiles, plastic, metal, brick or concrete. A child's swimming pool, stock waterer, or even professional pond plastic lining can be used. Alternatively, a professional pool can be made, wherein the hole is lined with bricks mortared with concrete (which may be more affordable than concrete alone), and then optionally surfaced with glazed tiles, coated with water-resistant non-toxic paint or oils, or left untreated. If these celebrated materials are not at hand, compact the bottom and sides of the pond as much as possible and line it pond with old bedding from the coops and kennels, and as much organic matter as possible. Tree leaves work especially well. Keep adding organic matter over the months and years: over a few months, they will solidify into a less-water permeable barrier, and over a year or so will condense into a sturdy barrier.

The pond should be at ground level, preferably with a gradual slope towards the center. Fish may be stocked in the pond, as they will help keep the water cleaner by eating goose wastes and potentially provide secondary income. If you can, train work beavers to keep up the pond as discussed in previous chapters.

The pond should be sheltered against evaporating winds, and (if lined) trees should be planted nearby to shade it from the hot summer sun (also to help reduce evaporation). 20 to 40 geese per acre of water surface is usually an ideal density (Holderread), but if the water is regularly muddied, if the banks are eroding, if plant life is being destroyed in the pond, the density of geese is probably too high. High concentrations of geese are acceptable if the pond is regularly cleaned and dredged.

Trees around the coops and ponds shade and protect the birds from the hot summer sun, and shield them from the cold winter wind. They also provide good places to rest during the day. Fruit trees provide additional nutrition to the birds whenever waste fruit is dropped from the tree.

However, brush should be avoided. The area surrounding the coops should be entirely free of bushes so that eggs are not laid in them, and predators find it more difficult to even attempt to hunt the chickens and geese.

While the size varies by location and each farmer ought to undertake their own trials by observing the range of their birds unpenned, if birds are to be penned, we recommend penning like cattle. Too many birds on a small area destroys the vegetation and reduces hygiene.

Sanitary Coops

Coops should be constructed in a way that allows them to be easily cleaned. Sometimes this means a coat of paint on the wood, other times it means metal sheeting or disposable components.

Change the bedding in coops as often as economically feasible. While some farms do not ever change bedding, or do so once every year, we change our bedding every month or every two weeks, depending on how much the birds are staying inside. The birds will peck at the bedding and eat some of their wastes, and this will make the birds more likely to become sick.

For bedding we recommend wood chips or straw.

Each chicken should enjoy 3.33 feet of coop, but we have successfully kept birds so that each one enjoyed only about 2 feet of coop or less when we allow them to wander during the day. The issue is pressed only when the birds are not allowed to roam freely. When they are, the only constraint is roost space, and each bird will occupy about 1 foot of roost, and the roost will occupy just over 2/3 of the coop.

Free ranging birds will choose where they sleep at night, and they may sometimes all crowd into one coop by choice if they like the rooster in there. Don't try to argue with them – they know best. It may be that they need to crowd for body heat, or for socialization. If you provide two coops and only one is used, be patient. Eventually the head rooster will lose some dominance and a subordinate one will move some of the flock over to the empty coop. But still it is amusing, we once had all our chickens in one coop except for a single rooster and his hen, who were in the one next door!

The roost can be as simple as a ladder formed by 2x4 lumber posts. We find best success with cylindrical dowels as the "steps" in the ladder. It is meant to imitate a tree branch. Plastic and metal pipes are bad perching material, as the birds cannot grip them. Cross bars should be at least 1 to 2 inches in diameter to sustain the weight and make perching easy. Thicker is acceptable, but thinner and the birds won't be able to grip the bar (see Picture 1)

Needless to say, geese do not need or want a roost. They do enjoy a floor with nice, soft bedding and will sometimes make nests in it.

Provide waterers that do not allow filth to enter into them. They should be suspended above the floor on blocks. While the birds will enjoy the fresh water of a pond or puddle nearby, they do enjoy drinking in their coop as well (see Picture 2).





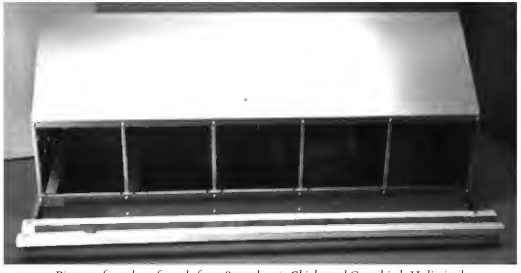
(Left) Picture 1: Chickens perched on a roost for a midday nap, guarded by the famous head-rooster Curley. Curley, like all our roosters, was trained to bring them in to nap: this reduces the risk that they are attacked during their siesta. Curley will monitor the situation and will tell his hens and subordinate roosters when it is time to work again. The good rooster stands guard against foxes, coyotes or other intruders, but allows in his masters (and sometimes their guests). This particular rooster was the best we ever had, and the favorite of the flock (notice his large harem behind him). He was especially famous on the farm for once having encountered a coyote and beat it up with wings, beak and talons. The other roosters helped him chase it away and later re-enacted the victory through rudimentary theater: one rooster would "stalk" Curley doing a decent imitation of the coyote, and then Curley would pretend to attack the "coyote" while the hens and chicks watched. Each time the "coyote" was chased off, the birds would crow and make all kinds of noise. (Right) Picture 2: the waterer is shielded against filth, is elevated so filth is not accidently kicked into it, is easy to clean and easy to access. Birds find the slippery metal hard to perch on!

Provide nest boxes to lay eggs in. Chickens like to lay in bushes or other sheltered spots. You can provide a better spot than that!

The box can be premade, or made to standards: the entrance height of the box should be 14 inches, the interior minimum height should be 18 inches. The width should be 1 foot. A roof should be provided to shelter the eggs from birds landing on them, or from poop or filth contaminating

them. A small perch should be placed before the nest box (unless the box rests on the ground) to make the birds feel more comfortable. No back should be provided for the box to facilitate cleaning: put the boxes against the wall of the coop. A soft mat, straw, old leaves, or other material to cushion the eggs from breaking is also comfortable for the birds. Provide one box for every four hens.

Leave several eggs (or wooden or plastic imitations) in the nest boxes to encourage the chickens to lay in them.



Picture of nest box, for sale from Stromberg's Chicks and Gamebirds Unlimited

Geese do not need nest boxes. They nest on the ground, and spend time to collect good nesting material in a safe spot. You can give them an excellent place to lay eggs (in their kennel) and provide them with good bedding and nesting materials so they will make themselves a nest and lay their eggs carefully there.

Ensure that feed is stored nearby for convenience. Feed should be stored in watertight, rodent protected containers. We recommend using garbage cans, clean drums or dry water barrels. We premix feed for further convenience.

Some coops are heated and artificially illuminated to promote egg laying in the winter, but this rarely works for chickens allowed out of the coops: one step outside and they know it's winter! Smart birds. Keeping chickens inside improves total production, but does nothing to improve quality: chickens allowed to graze on weeds and insects have, by blind taste tests undertaken with our customers, better tasting eggs that are cheaper to produce.

Keep harvested eggs nearby for convenience. A shed with refrigerators does nicely, or a cellar if electricity is not available. Eggs should be stored so they do not get cracked in soft containers that hold the egg in place (like an egg carton). High temperatures break down whites and multiply bacteria to spoil eggs; low humidity evaporates the moisture in the egg. High humidity encourages mold and bacteria. It is not as complicated as it may sound, and you'll quickly get the hang of it: raw eggs are very tolerant of bad storage conditions as their beneficial microorganisms will typically make up for what deficiencies there may be in your care.

Clean the eggs before storing them by wiping off filth with a damp rag.

A breeding facility nearby is also useful. It can be a small coop that a chosen rooster and hen can be kept together in until they are mated. Include a window for observation from the outside. A place for the hen to lay her eggs should also be present so the eggs can be segregated from others and the father and mother known.

Breeding is typically uncalled for: trust the chickens to select among themselves their very best, and you will gradually improve your flock this way.

Chickens require clean dirt to bathe in to keep themselves safe from parasites. Both chickens and geese require clean dirt and small rocks for grit in their gizzards to aid digestion. Till the area around the coops. This also integrates chicken wastes into the soil, where they will decompose better and pose less health risks to the birds.

All your birds risk getting internal parasites because they are eating wild foods, sometimes insects. However, this chance is minimal if the birds are otherwise healthy. If they get sick from parasites, they will typically respond well to antibiotics. A consultation with a veterinarian usually solves the problem, and educates you on how to avoid and treat it in the future. *The Chicken Health Handbook* and other veterinary textbooks are updated with modern understandings of the diseases chickens and other animals face.

Coop Construction

Coops can be constructed out of many materials and made to be stylish buildings or rudimentary shelters. Depending on the location, solid walls may be required, or mesh fence walls may suffice. We have used surplus premanufactured garden sheds, constructed A-Frames out of timbers, and even converted an old truck trailer into a coop.

But more niggardly constructions are used: the most affordable coop is made of straw or hay. Stack square bales into a square, leaving a gap for a door. The roof may be as simple as a tarp (make sure to brace it underneath with some 2 x 4 timbers and stake it down so that enterprising lions and coyotes don't get a free snack), but wood panels are better. Better still, the hay bales may be angled into an arch to form a "hay igloo." The nest boxes and roost are placed inside. Usually, the hay structure is so small that a roost is impossible, and the birds nest on the ground. A door is made by putting a sheet of wood in front of the door hole and securing it with rocks or blocks. After a year or two, the hay begins to mold and is composted, a new structure is erected in a new location to replace the old.

An improvement to the hay igloo is the construction of a wood frame (complete with doors and windows, sometimes) and hay bales are used to fill the areas between the frame's studs. A more sturdy roof is gained in this way. Sometimes, the frame is simply covered with a tarp or canvas cloth to make a tent coop.

Almost equal to the hay igloo coop is the cinderblock coop, of a similar construction. We have seen old cars made into coops, and even log cabins made into coops. Some coops have a garden planted on top, or are dug into hills as "cave coops."

A mobile chicken coop is sometimes in use by farmers. These coops have wheels and the mesh floor allows chicken droppings to fall to the ground underneath it and fertilize the soil. Some are built so that the coop sits on the ground and the chickens graze the vegetation and grass, insects and other things to eat while the farmer moves them about the field every few days or so. This seeks to combine both a penned system of management and a free-range system of management, but

accomplishes both poorly: the environment is not well controlled to induce greater egg production, and the chickens are not able to forage for the foods they'd best like.

One feature some farmers may require is a lock on the door of the coop to prevent unwanted humans from entering the coops. Vandals and thieves are a problem for some farmers, but not for others. We lost an entire flock to such criminals, though, and are apt pupils: we advocate, if not using locks, than retaining the ability to use them.

Starting Flocks

Starting a flock of birds can be undertaken in several ways. Adult birds can be adopted from a neighbor or animal shelter and their fertilized eggs will gradually build out a flock, wild populations can be domesticated and their populations increased through proper management, or baby birds can be ordered by overnight mail. This last convenience was unavailable in Tull's time, and is a wonderful delight of modern life. However, in Tull's time, there were breeders who specialized in chickens, and both adult birds and chicks would were available.

Another method is incubating the eggs yourself. When the farmer must play the role of the mother hen or goose, the farmer must be able to control temperature and humidity is a very hygienic environment.

Hens and geese are the best mothers of chicks and goslings

Build your flock by starting with birds in a box, and then allow the birds to raise you a new generation.

When starting your flock you are required to act as a mother and father to the birds, something you are not going to be as good at as an adult bird would.

There are other advantages to birds raising birds. When dealing with birds in a box, you have to brood them yourself. This requires a box that can be kept warm in a sheltered and protected area, and lots of labor. If the baby birds are to get any exercise (which they ought to, if they are to practice flying, dust bathing, running, mock fighting or any of the other skills they'll need later in life), they will require your full attention in a protected area secured against predators, cold or other threats to their health.

Few humans can afford the time to properly raise baby birds in this way. Most humans keep their birds locked up in small brooders all the time.

If they were being raised by a mother (and in some species, also a father) bird, she and he would spend the necessary time that every individual baby bird would need. They would sing to them constantly (we do our best by playing music). They would lovingly rub each one (which we can do too: it improves the health, longevity and production of each bird later in life).

We try to allow the birds to come out of the brooders 2-4 times per day for at least an hour at a time (until they get tired out and need to go "home" to nap). This time is also spent cleaning their brooder thoroughly (another time intensive task not undertaken by most farmers nearly enough). We use a special enclosure outdoors that is warm for this purpose, though the corner of a garage or barn with nothing bad for the baby birds to get into will do well enough. Remember: if there is something that should not be eaten, they will find it and eat it!

Give your baby chickens a toy: a piece of newspaper or paper or some leaves. They will play a chasing game and get good exercise, social and foraging skills and develop important reflexes. One will grab the leaf or rip a small part of the paper and run around being chased by the other chicks until it surrenders the toy. Geese do not like toys, but they do like things to chew on. Giving them a radish, turnip, carrot or other hard chewy nutritious thing will entertain them for hours, encouraging healthy growth, improving trainability and reducing damage to the brooder.

Remember, though you are specifically training your rooster as your work animal, all the hens must be trained as well to obey basic commands and your care for the young animals begins with intellectual and physical improvement.

Mixed Breed Flocks

We – and Columella – recommend choosing several breeds.

The chief importance of many breeds lies in the natural hybridization and vigor of the flock that will result.

Different breeds have different instinctual behaviors of foraging, roosting and laying, and when a variety of these behaviors are present, the other breeds acquire or learn the instinctual behaviors which are best for the environment of the farm. In example, some chicken breeds sleep on the ground, and others sleep perched, some forage far from the coops and others forage closer to the coops, some are more gregarious and flock better than others. Geese have a variety of instinctual behaviors that vary by breed also: some explore more and others stay closer to home; some spend more time on the water and others spend more time on land, some sing often and others do not. On any given farm, at particular times of year, any one of these behaviors might be advantageous. The birds are not slaves to instinct, but do acquire and apply observations and undertake some critical thinking: if they notice that some of their friends are gaining more food or more comfort, they will follow suit.

There are differences within breeds as well: some individuals are naturally better mother hens or geese, others are naturally better roosters or ganders, some eat and gain and lay better than others. However, just as each breed of dog has its own classic behaviors, each breed of chicken or goose does also, and while Golden Lab will do the security work of a German Shepherd, it will never do it so well as a German Shepherd; the same is true for breeds of chickens and geese.

Bonding between individuals creates families, families creates flocks; methods of communication in birds that lead to social bonding and ability of a human master to command; limited notes on bovines

The sociality of bovines and equines has already been explored at length, and the similarity of goats and sheep to bovines and equines does not require many additional notes. Some words should be made on the socialization of birds, especially chickens.

Individuals will bond together to form families, and families will bond together to form flocks or herds. In some species, the male is the dominant member of both flock or herd and family, in others species, the male is dominant in only one, in other species, the male is dominant in neither. In some species, bonds are nearly permanent, in others, it is seasonal. Different species have different family compositions, with varying numbers of "wives," "husbands," "children," "elders," "servants," and "in-laws." Human family terms are applied to animal families.

Chickens will typically be defined by a harem family unit, dominated by a rooster. The flock is governed by "head" rooster, who also has his own family to govern.

Hens will bond to all the roosters in the flock, and will more closely bond with the head rooster than subordinates, bonding closer to the secondary rooster than the tertiary, and closer to the tertiary than to the other roosters, etc. This is mirrored in how the roosters bond with each other: the roosters will bond to their superiors and become a part of their harem.

Chickens and roosters will bond to a rooster by sexually submitting to them. Roosters bond additionally by sparing periodically. The sparing does not (usually) change the relationship between the two roosters, though we did one time observe such a shift in leadership.

Occasionally, roosters will bond in a pair, and will share their hens, their food and all other resources, and will defend each other in sparing matches or against real enemies. They will always be near to each other. These double-roosters share rank, and so it is possible for a flock to have a double-head, a double-secondary, etc. One will be slightly more dominant than the other, which will be observable by how one will always decide when to sing, when to eat, when to drink, when to mate, etc. Yet the subordinate will not submit sexually to their partner.

Roosters will either escort their hens beyond the home territory or try to keep them at home. Of those roosters that escort their hens beyond their home territory, some roosters will lead their hens to resources, others will simply follow their hens and keep watch for them while they eat. If danger presents itself, the rooster will bring their hens back to the home territory or will encounter the threat. Some roosters keep their hens closer together when out of the home territory, others do not.

Roosters will communicate to their harem by song. A song is sung when the rooster has found an important resource: food and shelter each have their own song. A variant will be sung when the hens are to follow the rooster to the resource. A song will be sung to alert the hens to potential danger, a different song will be sung to signal that the danger is past. A different song will be sung to signal all is well, and another to return home. Birds respond very well to human voice commands, as they perceive them to be a kind of song. Whistles also work well.

Roosters also communicate by dance. A dance is performed with one wing down towards the hen as the rooster shuffles in a circle around the hen. This is a courtship ritual that bonds the hen to him. The hen will often sexually submit to the rooster after the dance to signal acceptance. These dances are difficult for a human to imitate.

Hens will sometimes sing as they eat, brood or explore. This, more or less, helps the roosters keep track of their hens as cowbells aid human herders keep track of their cows.

We have observed several songs that were inaudible to human ears. One, which was accompanied by the clicking of the beak, seemed to signal contentment, another seemed to signal distress.

While the songs are largely instinctual, each flock will develop its own variant songs that are sometimes incomprehensible to other flocks. Experiments undertaken that segregated individuals and entire flocks demonstrated this.

Experiments in exposing the chicks to various music demonstrated that these differences are obtained early in life: chicks exposed to continual Bach sang differently than those exposed to Mozart, and both sang differently to those exposed to Beethoven, and the chicks exposed to no music at all not only sang differently, but their singing was exhibited later in life and training them was more difficult. Thus, the farmer should expose birds to music early in life.

Occasionally, an immature rooster will bring a company of hens to good grazing, and then abandon them, running back to the home territory without them. The behaviors of the roosters, while instinctual, are also learned and improved upon – just like in bovines and equines.

Roosters will spar without hurting each other when things are generally peaceful and their attention is not required, and also first thing in the morning. They will try to jump over each other, or put a foot on their opponent's back. The winner and loser both face new sparing companions. This play behavior reinforces the bonds and social structure of the flock, and helps hone reflexes required in their daily lives. Occasionally, roosters will try to play with you. Hold your foot at their eye level and they will spar with it. Hold it above them and they will submit. Gently pet their backs with your foot and "win" the game. Or, to give them exercise, draw out the match by tapping the ground behind them to "jump over" them. Roosters do appreciate a good hug every once in a while, but not during playtime. Hens are always ready for a hug. Some really enjoy hugs and enjoy being carried around in human arms even more, begging for a ride or helping themselves whenever a person comes near. They are very friendly creatures.

Adult hens rarely play. One game they do enjoy is the sprint: sometimes hens will run for no reason. Hens sometimes fight to reinforce bonds and the social structure of dominance: when they do, they rarely harm each other but will peck and cause pain.

The roosters will tear feathers from the backs and tails of their favorite hens. This does not harm the hens, and does not even reduce (significantly) their heat loss in winter, as judged by their proximity to (a measure of desire for) heat lamps and other birds in experiments we undertook. Occasionally, skin will be broken by this courtship, but antiseptic can be applied in combination with a foul tasting paste that discourages further "love" of the roosters.

Both roosters and chickens will bite human fingers (softly) to demonstrate love. They appreciate gentle touch, especially between their eyes on top of their head, on their necks, their bellies and on their wings and tails.

Roosters improve the production of their hens significantly. In experiments, roosters were alternately removed from their hens or never introduced to hens and it was observed that foraging hens were more diffuse, some could not find their way back home, egg production was reduced and feed consumption was reduced. Hens do not appear very emotionally disturbed if their roosters disappear, but roosters become very stressed and require at least one companion: the roosters "love" their hens and fellow roosters more than their hens "love" them.

The best benefit of roosters is the round-up. Roosters can bring all their hens to the coop upon command, and this saves much time when the birds need to be closed in for the night, or handled for veterinary or other care. Roosters also encourage hens to lay near to their coop, and will fight off many predators. The predators they are not equal to (such as hawks) they defend against by bringing all their hens to safety: upon a call, their hens will run for the shelter their rooster directs them to and wait until their brave rooster, who still watches for the hawk from a position of less safety, tells them the danger is past.

Roosters train hens better than people can, and hens more readily listen to roosters than to people.

Ganders serve a similar purpose with their geese. Like chickens, ganders and geese communicate through song and dance. Their "vocabulary" is similarly extensive, but they do have special greetings for people, animals and even buildings or plants of special importance. The song is sung by all the members of the family unit simultaneously, and is sometimes hard to pick out as each bird repeats the call they heard.

As they migrate around the field, they sing. Typically it is the "all is well" call, and this helps each individual keep up with the family. When one member is lost, the family typically does not go back for them unless the distress call is both sung and heard: the "all is well" song can drown out emergency calls, sometimes.

Geese and chickens, because their communication is similar, will sometimes bond.

Free range cattle also express themselves through song and dance, and have a similar vocabulary to chickens and geese, but their different songs and dances usually prohibit a close bond between the species. The socialization of bovines has already been discussed at length in previous chapters.

All animals on a free range system will improve their natural ability to communicate, as it is in their interests to do so, as it is in the interests of any wild or semi-wild social creature to be able to communicate with members of its own species.

Commands do not exist, per se, from the animal leadership. Leaders typically simply express their observation of a resource desired by subordinates or a threat. The ability to observe opportunities and threats builds the leadership position of an individual more than any play fighting, and that leader gains extra rations of food and more sexual activity in return for their services. Leadership is also earned when one animal comforts another while the comforted animal is injured or sick. Some roosters have built a large harem simply by standing by and singing comforting songs to hens that are sick, injured or in distress.

Asocial creatures have little need to communicate and are thus very difficult to train. Those who would undertake the husbandry of turtles for eggs instead of birds will notice this difference immediately. Turtles are nearly impossible to train well.

Training animals allows for improved efficiency because it is in the interests of the natural social structure of the domesticated species to ensure that even the least among them are well cared for. The job of the farmer, to care for each one of their animals, is easily outsourced to the leadership of the animals themselves.

We look at our animal leaders as valuable partners in production, and the respect we provide them is well earned.

One situation where training does not matter is if the animal will be killed quickly: it does little good to train animals to round themselves up if they will die the first time they do it. It simply is not worth the expense. Yet, training cows in a cow/calf operation to round themselves up (or several bulls to round up their herd) does pay. Another situation where training is not worth the expense is when animals are caged and not free-ranged: the animals are always where and how the farmer needs them, and there is no need for them to adjust their behavior.

Breed selection

While each breed has its characteristics, it would benefit the farmer to trial the various breeds available from their local breeder and their neighbors before settling on a flock or herd composition. Each breed reacts somewhat differently under different circumstances, and individuals within each breed sometimes break the mold.

With chickens, egg color is very important as a variety of egg colors improves customer satisfaction when selling in a CSA, but some wholesalers will not buy anything but white or brown eggs. It is best to establish a flock composition based on color eggs, and then giving consideration to the fact that with a variety of instinctual behaviors. With cattle, it is occasionally necessary to raise

a particular breed: in example, the popularity of angus cattle meat has made it more demanded than other breeds.

Early training – an example in birds

The importance of early training in bovines and equines has been explored in depth, and birds similarly demand lots of attention when they are young. If you treat the birds well when the first arrive, they'll grow old enough for you to raise them and enjoy their help on the farm!

The birds should be handled as often as possible to accustom them to being touched by humans. By picking them up and holding them carefully, stroking them lovingly, you teach the birds to trust you and how to hold still when held – an important skill for adult life (they will need to hold still for veterinarians, for showing, for transport during emergencies and countless other reasons). Talk to them: despite outward appearances they are actually intelligent and listening, and are learning English. In our experiments, birds who were talked to more obeyed commands better later than those who were not talked to much or at all.

Though this is labor intensive, it will save labor later and this labor is easier than what you would otherwise face. It is especially excellent work for the farmer's children.

If the birds peck or scratch at you when you handle them, this means you need to handle them more to accustom them to your touch. Handle them gently. Gently stroke their feathers. Talk and sing to them, accustom them to your voice. Carry them about and never let them down when they struggle. Only let them down when they are calm: you want to dictate to them when it is time to leave your hands and if you reward their struggles with freedom, you will teach them a bad lesson.

One significant disadvantage to receiving birds in a box is that it is in the first 3 days that birds usually learn to recognize friends and family. This behavior is, as in humans and all animals, governed by the development of the fear response in the brain. Birds that are less than 3 days old are simply too young to feel much fear; when their brains mature enough to develop fear they will be more hesitant to make new friends and familial bonds.

The first 3 weeks are most important for establishing a loving and respectful relationship with the birds. Gail Damerow writes in *Your Chickens*, an excellent introduction to raising chickens that nicely accompanies her authoritative *Chicken Health Handbook*, that pecking orders and social structure among a batch of chicks is established by that age. An introduction to the older chickens should be made by this point, as well: we have a fenced off area that the baby birds can meet the older birds without the older birds pecking at the baby birds, or the baby birds escaping off from. It is rare that chickens will adopt chicks that are not their own, but it is good that all the chicks learn the social structure of the flock before they are introduced to it: it will reduce fighting later on. Additionally, the chicks will learn all the songs they need to know so that they can better avoid predators, be herded by their roosters (or herd the hens, if they are roosters), and otherwise undertake the necessary work of chickens.

One of our neighbors undertook an experiment of his own after noticing our work. He segregated one chicken from the flock at a young age and noted that it still "peeped" like a chick even long after the other birds had started singing like adult birds. Upon reintroduction, it stayed near to people and was unable to socialize with the other free-ranging birds. It never learned how to sing like the other chickens, did not know how to forage for food, or roost. After several months of no improvement, the bird was "rescued" and became a house pet.

One important command trains the birds to come when called. We have watched the pained efforts some other chicken farmers undertake to capture their birds when necessary, for harvest or

for veterinary care or for sale. Ours come when we call, and those that do not are brought to us by the roosters. Anyone who has tried to catch an unwilling chicken will agree that a minimal investment in this basic training is well worth the cost.

First train them to come to the sound of a bucket of grain. It is necessary only to feed them a very little bit later, but be generous with the young chickens so they will remember the sound well. Shout "chickens!" (or "geese!" if you're dealing with geese, or "cows!" if cattle, etc.). If there are many people who work with the birds, no three of them will be able to make the call the same way. Obtain some bells and ring a particular tone as you shake the bucket, and they will always associate the two – if they cannot hear the bucket, they will hear "chickens!" or that tone bell and come.

Teach them, too, to "sit," if you can, by holding them in your arms, commanding "sit," and rewarding them when they finally stop trying to escape. This requires no verbal or audible command, but should be taught through tactile association: when they are in human arms, they need to hold still. "Get up!" is a good one too: no more stooping down to pick up birds because they'll come into your arms willingly!

A very good command to know is "go home." This can be verbal, or a different toned bell (a higher or lower pitch than "come"). Teaching the birds to stop whatever they are doing and return to the coop is essential. Sometimes you need to run an errand and do not want to leave the birds out of the coop after dark, and they need to come home early. Sometimes an automobile is being worked on and you don't want any risk of them eating some coolant fluid. A thousand examples come to mind why you might want to coop your chickens before they are ready to settle in on their own choice. Train them in this as soon as they are moved to the adult coops.

By the time you receive your birds through the mail, they are usually on their second day of life and very scared from being transported in a box. Don't worry, though. Through constant handling and training, the birds will begin to recognize you as a trusted friend, and will be calm when you handle them for veterinary care, for showing or for any other reason.

Do not clip wings

Do not clip the wings of the birds. Their resource to flight is a necessary one if they are to survive predators.

Selecting breeds – examples of chickens and geese demonstrates principles

The thousands of breeds of chickens and geese that exist prohibit an even cursory examination of them, but a few will be discussed to demonstrate how to compare breeds. Though we have had success with them and praise them, it does not preclude other breeds as being better for your farm. Each farm is a unique environment. A discussion with breeders or observations of the flocks of neighboring farmers will yield enough information to make informed decisions, but if in doubt, order a small batch of each kind of breed and undertake your own observations: we recommend ordering a test batch of at least 2 roosters and 2 hens, but more examples are better because it may be possible that in your sample you have obtained a neurotic bird that is not true to breed.

Selecting breeds – an example of geese

There are many breeds of geese as well, but a few that are most commonly relied upon and these will be discussed limitedly. First, geese will be discussed because there is more variation between the breeds than in chickens, and illustrates the concept better because of this.

Most geese trace their lineage to one of 2 species: the Asian Swan Goose and the European Graylag. There are 9 principle breeds in America: in the Swan Goose line is the most common, and in this line the African and Chinese geese are most popular. In the Graylag line are the Embden, Pilgrim, Toulouse, American Buff, Pomeranian, Sebastopol and Tufted Roman. We like these as well as we like the Swan Geese. In addition to these 9, 2 other breeds have been very recently standardized by the American Poultry Association: the Canadian and the Egyptian (which are less productive egg layers, but hardier animals under many circumstances).

Geese are divided into lightweight, mediumweight, heavyweight and ornamental breeds. Lightweights are typically used for egg production, heavyweights are typically used for meat production and mediumweights offer the best (or worst) of both lightweights and heavyweights. Holderread summarizes the breeds in a way that most people might:

Breed	Weight	Weight: M/F	Yearly Egg Production	Mothering Ability
Chinese	Light	10-Dec	40 - 100+	Poor / Fair
Tufted Roman	Light	10-Dec	25 - 35	Good
American Buff	Medium	18 / 16	25 - 35	Good
Pilgrim	Medium	14 / 13	25 - 40	Good
Pomeranian	Medium	17 / 15	25 - 35	Good
Sebastopol	Medium	14 / 12	25 - 35	Poor / Fair
African	Heavy	20 / 18	20 - 45	Fair / Good
Embden	Heavy	26 / 20	25 - 35	Fair / Good
Toulouse - Dewlap	Heavy	26 / 20	20 - 35, sometimes 60	Poor / Fair
Toulouse - Production	Heavy	20 / 18	25 - 40	Fair / Good
Canadian	Ornamental	12 / 10	4 - 8	Excellent
Egyptian	Ornamental	5.50 / 4.50	5 - 8	Excellent

Typically, as with most egglaying animals (whether they are birds, reptiles or fish), advantages in weight and / or eggs comes at the expense of mothering ability and general hardiness. A large or prolific egglayer will necessarily be a worse mother and less hardy; a hardy animal won't be spending its precious energy on attaining great bulk or reproducing.

Ultimately, as with chickens, a flock with multiple breeds is best.

Some discussion on the breeds

The relatively few breeds of geese allow some discussion into their advantages and disadvantages.

In America, more Embdens are raised commercially than all other breeds combined (Holderread): goose meat is more popular than goose eggs, and Embdens put on weight faster than other heavyweights. Toulouses are one of the most popular breeds among small farmers, as they seem to combine egg laying and meat production capacities best. But their breeding stock is very expensive, and they do not reproduce readily. Pomerians are very popular in their native Germany (where there are numerous subtypes), and are beginning to come into vogue in America.

American Buffs are also popular among small farmers, and their stock is somewhat more affordable. Pilgrims are also favored because, from hatching, the sexes of both male and female are easily discerned and those farmers seeking to reduce the number of males (or segregate males for meat production) find this attractive. Farmers who would undertake breeding also find this attractive. Sebastopols are typically raised for their feathers because they have long, soft, curly feathers. Sebastopols are also gentle by nature and are good companion animals, but are less suited for moist climates than other geese because of the way their prized feathers allow them to get wet and cold. Breeders of Sebastopols should trim the feathers near the vents of the birds, as they sometimes get in the way of procreation.

Chinese geese rival the Embdens for popularity and are good egg layers. Chinese are also efficient eaters. Their stock is affordable, but they produce lean meat (which is undesirable in geese) and are very "talkative," which can irritate some farmers. Both Chinese and Romans are good security animals, and are quite robust against environmental or other physical challenges. Romans produce fattier meat than Chinese, but require more ganders than other non-ornamental breeds for breeding. Both Chinese and Romans can be quite affectionate and loyal to those people and animals that they bond with, and are able to make friends if properly introduced to someone.

Canadian geese are typically raised for staged (or "canned") hunting, as companion animals or for improving other breeds. They bond readily, but will typically bond into 1 goose 1 gander pairs. Canadians are strong fliers, nomadic by nature and will leave the farm if their wings are not clipped.

Egyptians have very long legs suited for marshy areas, and are kept for many of the same reasons as Canadians. They are highly efficient eaters. They excel as security animals, being territorial and fearless, but sometimes harass other livestock if they get it in their heads that they don't like them: they may injure or even kill other birds that invade their territory! They are one of the strongest of all birds and it is a mistake to attack them. They are aggressive during breeding season, but defensive at other times of the year. However, they can be trained to tolerate other birds if the farmer takes the time. They typically mate in pairs.

Making a new breed suited for your farm – an example of longhorns

With thousands of varieties of chickens, there is no possible way to discuss the advantages and disadvantages of them all. Similarly, the farmer is confronted with thousands of varieties of cattle, goats, sheep, dogs, and other livestock. However, a mixed breed flock or herd is always best and will evolve, if the farmer takes care, into a new, improved breed ideally suited to the demands of the farm. The methods of choosing what component breeds begin your new breed are best illustrated by the Texas Longhorn, and the chicken.

The Texas Longhorn is a breed of cattle known for its characteristic horns, which can extend to 7 feet tip to tip for steers and exceptional cows, and 3 to 4 feet tip to tip for bulls. Horns can have a slight upward turn at their tips or even a triple twist. Texas Longhorns are known for their diverse coloring. Due to their innate gentle disposition and intelligence, Texas Longhorns are increasingly being trained as riding steers.

The first domestic cattle to reach the Americas were imported from Spain from about 1493 and many escaped. Later, immigrants from England, France and other European countries brought cattle to America, and some of these escaped, too. These escaped cattle formed wild herds and were then subsequently pressured by the harsh local conditions into a new breed that was able to survive on poor desert vegetation. They became able to put on weight quickly, became very disease resistant, and kept lean meat (an undesirable trait until the 20th century when cattle were used not only for milk and fat meat, but also for the production of tallow and other fat energies. However, lean meat is now a very desirable trait indeed!). In 1927, the breed was nearly pressured to extinction by ranchers who saw the wild cattle competing with their domestic herds and if it were not for the United States Forest Service (who collected a small herd of stock to breed in the Wichita Mountains Wildlife Refuge of Lawton, Oklahoma) and the heroic efforts of J. Frank Dobie of the Texas State Parks, this magnificent breed would have died out. The US Forest Service and Texas State Parks cared for them as curiosities, but as ranchers began to see these curiosities in a new light, they began to understand how the Longhorn could improve their herds or take the place of their more traditional breeds of cattle.

It has since been discovered that Longhorn cattle have a strong survival instinct and can find food and shelter during times of rough weather. Longhorn calves are very tough and can stand up sooner after birth than other breeds. Longhorn cattle can breed for a long time, well into their teens. There have been cows that have bred for up to thirty years. Some ranchers keep Longhorns for their easy calving. A Longhorn cow will often go off on her own to a safe place to have the calf then bring it home. They are also known to hide their calves in safe places to avoid predation, sometimes causing difficulty for ranchers, who may need to work on the animal.

When making a new breed, imitate the natural processes that developed the Longhorn: combine semi-random breeds of animals (pre-selecting breeds that you believe might have desirable characteristics) and then let the pressures of farm life take care of the rest. The good characteristics will be preserved and the bad ones weeded out through Darwinian selection.

Alternatively, the farmer could undertake to reserve breeding males and breeding females, and attempt to scientifically combine the breeds into a more useful one, but this requires infinitely more work, and the wisdom of the farmer cannot possibly be compared to the wisdom of nature who, by the pressures she applies to the animals, discourages those habits and traits that are detrimental to the farmer and the breed and encourages those which are useful.

Masanobu Fukuoka undertook this kind of breeding with success, and though you may not see results in your lifetime, like planting a forest for your grandchildren to harvest, it is an investment that is still worth making.

Besides, in the meantime, you will enjoy all the benefits of a mixed flock or herd, which are many: together, a large flock or herd of several kinds of breeds functions better than a single breed. Not only is there improved disease resistance because not all the animals are genetically identical (or nearly so), but because the animals aren't identical in their temperaments, they are better able to care for each other and preserve the flock or herd from danger. Trust the natural bonds that form between your animals: when one breed is able to function best, it will do its best to ensure that the deficiencies of its friends are compensated for.

Compose your flock or herd based on production goals: work animals can be trained from any breed. When assembling a mixed breed flock or herd, ensure the work team is of multiple breeds as well

When there are thousands of choices, designing a flock or herd make-up is little different than when there are few choices. Chickens present a typical example, no matter what animal the farmer is going to raise.

Chicken breeds vary by temperament and instinctual behavior, in the size and color of their eggs, their ease of weight gain, their mature size, the quality of their feathers and other factors.

In terms of their capacity to function as work animals, some breeds produce better roosters than hens, and some produce better hens than roosters, and only a few produce both good hens and roosters. Yet the color and size and number of eggs matters more than behavior, and just as the farmer who will raise Angus cattle because of the constraints of contracts will likely choose angus work bulls, the productive qualities of the animals is paramount to their trainability. All animals with enough work can be trained to work very well, and the farmer must keep an eye to their production.

We advocate, if possible, in a mixed breed herd or flock to have several breeds of work animals as well: their different temperaments and instincts will compensate for whatever deficiencies their team has, and whatever deficiencies in training their master has provided.

As with any work animal, make sure that the work animals bond well in their youth.

Notes on some chicken breeds

Australorps

Australorps produce excellent roosters. These roosters work well with other roosters, and tend to keep hens in groups. The roosters try to keep their hens close to home. The roosters are very brave and will defend their flocks even if they risk injury in doing so. The roosters are easily trainable, and love to help their masters: our Australorps enjoy chasing their hens back into the coop when it is commanded that the "chickens go home!" Their hens are difficult, however, as they are ungregarious and will strike out on their own. Yet the farmer and rooster may forgive them: they lay a great number of light brown eggs of medium size: they can, under ideal conditions, lay 364 eggs per year per bird. Most birds mature at about 6-7 pounds, but we have seen some gain more than 10 pounds. They are good mothers.

The roosters herd their hens with intimidation and force, and while they are rough with the hens, they cause little harm and the hens are not stressed by the treatment. When their hens are eating well, they sing to encourage them to eat more, and while they actively look for new food sources for their hens, they do not do as well as Ameraucanas because Australorps are more afraid the further they go from home.

According to the Australorp Club of Australia (http://www.australorps.com), the Australorp is Australia's "national breed" of chicken. They are "heavy" birds.

According to Wikipedia (relying largely on the book by Alanna Moore, *Backyard Poultry - Naturally*, 1998), Australorps were recognized in 1925 after Wal Scott, their breeder, petitioned the Standard of Perfection. The original stock used in the development of the Australorp was imported to Australia from England out of the Black Orpington yards of William Cook and Joseph Partington

in the period from 1890 to the early 1900s with Rhode Island Red. Local breeders used this stock together with judicious out-crossings of Minorca, White Leghorn and Langshan blood to improve the utility features of the imported Orpingtons. There is even a report of some Plymouth Rock blood also being used. The emphasis of the early breeders was on utility features. At this time, the resulting birds were known as Black Utility Orpingtons.

Orloffs

Craig Russell, in the SPPA Bulletin (1997, 2(2):5-6) has researched this breed well, and its interesting history is also presented in many encyclopedias. The Orloff, an Iranian breed named after Alexey Grigoryevich Orlov, a Russian Count who actively promoted the breed, is more commonly known the "Russian Orloff," or "The Russian." Count Alexey Grigoryevich Orlov (1737–1808) in 1770 was appointed commander-in-chief of the fleet, in the Napoleonic wars. Orlov commanded the militia of the fifth district almost entirely at his own expense, and he performed special services to the Empress Catherine by seducing the Princess Tarakanova and bringing her back to Russia for execution. After this, he rusticated near Moscow and began undertaking agriculture, breeding race horses (the Orlov Trotter) and, of course, promoting the excellent breed of chicken now known as "Russians." Russell reports they are still in use in Afghanistan.

Orloffs are very feathered. The hens are excellent mothers, gregarious, gain well and lay well; the roosters are highly attentive birds and, while not nearly so excellent as Australorps, perform very well indeed. They are "heavy" birds, and will mature at about 6 pounds. They lay medium sized light brown eggs. Both hens and roosters are easily trainable and friendly to people. They are talkative and hardy.

Ancona

Anconas are named after the town of Ancona Italy from which they originate and are excellent birds. They were popularized in England in the 19th Century.

They are highly aggressive as chicks and may injure each other and more mild breeds, but when older outgrow this behavior. The roosters are superior birds, bonding with their hens, following them everywhere and easily bringing them back home when danger or need presents itself. They are excellent companions for sick or injured birds. The hens easily bond with roosters and are highly trainable. They lay a modest amount of eggs (they can lay 180 eggs per year under ideal conditions) and gain a modest amount of weight. It is a "layer" breed, and the hens lay beautiful white, medium sized cream-colored eggs. They are hardy birds, and were bred for free ranges. They mature at about 4-5 pounds.

Roosters generally herd their hens with force, driving them as people drive cattle. They do not actively find food for their hens, but encourage them by watching for predators and keeping their hens in a tight group.

Orpingtons

Orpingtons are beautiful, big birds that lay beautiful, very large brown eggs. They can even lay in winter. They were originally developed by William Cook in Orpington (County Kent,

England) the 1880s. He crossed Minorcas, Langshans and Plymouth Rocks to create the new hybrid bird.

They are docile birds and often end up on the low-end of the pecking order. One of our chicks did not even try to evade being pecked by an overly aggressive Ancona, and one of our Orpington roosters would not even cry out if accidently kicked – and he would get underfoot frequently. They are very friendly birds, and like physical contact. They are easy to handle on free range situations, as they do not like to range far from home. The hens are great mothers, and the roosters take special care of chicks. Both hens and roosters will adopt chicks. They are typically double purpose, but can mature to be more than 8 pounds.

Ameraucana

Ameraucanas are best known for laying blue and green eggs, a very popular color among egg consumers both at Easter time and at other times of the year. They do not respond very well to training, are generally ungregarious and sometimes get "lost" and unable to find their coop. The hens do not respond well to the herding of roosters of any breed (though Australorps manage them best).

The roosters are subtle, but very effective. They sing and dance and find food for their hens, and, in tests where Ameraucana roosters were removed from the hens, were found to have been increasing feed consumption and speed the execution of commands. In short, while Australorps resort to intimidation to herd hens, and Anconas drive their hens with force, the Ameraucana lures them here and there as necessary through love. When he goes home, his hens want to follow. When he goes out to eat, they follow. He presents them with insects, grains and delicious treats, and they love him. They are always listening for his song: perhaps he has found something good for them to eat? No wonder they want to follow him home.

They mature at about 5-6 pounds, their blue and green eggs are medium sized.

The birds have "beards" and are very hardy. The fully feathered faces insulate the birds against the frigid cold of their home in southern coastal South America: winds from Antarctica bring the temperatures to below zero for months at a time.

Rhode Island Red

Rhode Island Reds mature at about 6 – 7 pounds, are very friendly, responsive to training, lay dark brown eggs (sometimes even in winter), are very hardy (even in high temperatures), and the hens are good mothers. The roosters do their jobs, but not so well as other breeds. Rhode Island Reds bond very well with other birds (even geese) and animals (even cows) and are highly gregarious. They are excellent layers.

Wikipedia reports that "In 1925, the Rhode Island Red Club of America donated funds for an elegant monument to the Rhode Island Red in Adamsville, near the baseball field and across the street from what used to be Abraham Manchester's restaurant. (The monument is now on the National Register of Historic Places.) A competing monument to the Rhode Island Red, claiming its creation not for the poultry fanciers, but for the farmers who grew them commercially in great numbers in Little Compton, was erected by the state in 1954 a mile or so (about two kilometers) south of Adamsville. The Rhode Island Red was originally bred in Adamsville, a village which is part of Little Compton, Rhode Island. One of the foundation sires of the breed was a black-breasted red

Malay cock which was imported from England. This cock is on display at the Smithsonian Institution as the father of the Rhode Island Red breed."

Leghorn

The Leghorn is very popular, the most popular in America. It was venerated by the ancient Romans as a sacred animal, and lays prodigious quantities of eggs. With a mature weight of about 4-5 pounds, it produces little meat. It is heat tolerant and cold tolerant, very hardy. They are well adapted to free range production, and like to roost in trees.

Columella teaches: mixed breed flocks of animals (especially chickens) have the advantage of camouflage

Another desirable result of a mixed-breed flock is camouflage: when all the birds look the same, it is easy for a hunter to pick one out and eat it. When birds are many colors, Columella and subsequent farmers have found that it confounds the efforts of hawks and other predators. The same is true for mixed breed herds of other animals.

Mixed breed flocks of chickens have the advantage of many different colors of eggs

Some customers will prefer one color egg, while others demand another color, and still some demand a multitude of colors in every dozen. Some prefer large eggs, others small ones. The needs of the customers should also be considered before deciding on breeds (even if the customers are the farmers themselves). The infinite variety of colors and sizes of eggs prohibit much discussion, but it has been our experience that during Easter in America, the demand for odd colored eggs increases.

Some customers will claim that the different colors and sizes taste different, but blind taste tests undertaken at our farm and with customers demonstrate that this is a false belief.

We sometimes sell mixed dozens of eggs, including chicken, geese, quail and duck eggs all together. These variety dozens are very popular with our customers who enjoy trying new things or that don't eat many eggs. We also sell uniform dozens of one kind of egg for those customers who need consistency. All our customers prefer the goose eggs best and chicken eggs second-best. Goose eggs have more fat and flavor.

Hygiene definition: reduced danger of infection and reduced toxicity; best accomplished not through sterilization, but through diversified microorganism communities

Hygiene is not "sterility," nor "cleanliness," but is a concept of a reduced danger of infection by microorganisms or reduced toxicity of their filth. This is accomplished sometimes through sterility, but sterility does not produce hygiene in the long term: by the processes of Darwinian selection, sterilization makes very dangerous microorganisms that are made more hardy by their struggles against sterilizing agents. Usually, hygiene is best accomplished by a diversified microorganism community: there are enough predators of microorganisms that none can become so numerous as to produce toxic amounts of waste or overcome the body's immune system. An excellent example is in food preservation: cheese that is preinfected with protective microorganisms

remains hygienic and good to eat whereas cheese that has been sterilized through pasteurization will spoil.

Mirriam Webster's dictionary explains the word's origins: "French *hygiène* & New Latin *hygieina*, from Greek, neuter plural of *hygieinos* healthful, from *hygiēs* healthy." It is "1: a science of the establishment and maintenance of health, 2: conditions or practices (as of cleanliness) conducive to health."

Animals are typically clean and hygienic. An unhygienic and unclean animal does not live long in the wild, and instinct leads them to perform hygiene and cleaning. If you provide ponds, puddles, dust patches or other means of cleaning themselves, if you provide them a variety of nesting or shelter areas so they can move about when one gets dirty (or, if not, that you provide them a coop that is easy for you to keep clean), they will always be in showing condition. Visitors to our birds always ask how we take the time to clean our birds: we always reply we have our birds clean themselves.

As said before, hygiene is not "sterility," nor "cleanliness," but reflects a low danger of infection by microorganisms or toxicity from their filth. To summarize, this is accomplished sometimes through sterility, but sterility leads to very dangerous microorganisms that are made more hardy by their struggles against sterilizing agents. Usually, hygiene is best accomplished by a diversified microorganism community: there are enough predators of microorganisms that none can become so numerous as to produce toxic amounts of waste or overcome the body's immune system. By understanding this, the difficult understanding that animals receive hygiene best through sanitation is gained and an appreciation for some filth is earned.

The immune system of animals is composed of mostly foreign bodies: friendly bacteria, viruses, retroviruses and fungi keep you and your animals healthy. Encourage the beneficial microorganisms within you and your animals as you would your cheese.

Incubating eggs

Many farmers incubate eggs, many do not. It is a preference based upon the farmer's skill and inclination, the availability of time and resources. That said, we rarely incubate eggs, preferring to allow mother hens and mother geese do the work of mothers, and when they fail to do so, we will buy hatched chicks and goslings from a breeder: we have found that the time and resources to incubate eggs is prohibitively expensive. This is also generally true for egg-laying reptiles.

Dr. Audrey Mc Elroy of the Virginia Extension Service of Virginia State University provides the basic guidelines in her 2009 publication, *Incubating Eggs*, excerpts of which are reproduced here for the benefit of the enthusiast or breeder, who would be the only farmer willing to dedicate the necessary time to this enterprise: business oriented farmers must acknowledge that outsourcing egg incubation or letting animals incubate their own eggs is usually more profitable.

Before setting eggs in an incubator, you must obtain or produce quality fertile eggs from a well managed, healthy flock which are fed properly balanced diets.

1. Keep the nest full of clean, dry litter. Collect the eggs early in the morning and frequently during the day to prevent excessive chilling or heating of the eggs.

2. DO NOT wash eggs unless necessary. If it is necessary to wash eggs always use a damp cloth with water warmer than the egg. This causes the egg to sweat the dirt out of the pores. Never use water cooler than the egg. Also, do not soak the eggs in water. If the egg is allowed to soak in water for a period of time, the temperature difference can equalize and bacteria has a greater chance of entering through the pores. Be sure eggs are dry before storing. Never place damp or wet eggs in a Styrofoam carton for storage.

3. Store the clean fertile eggs in an area which is kept at 55°- 60°F and 70-75% humidity. Never store eggs at temperatures about 75°F and at humidities lower than 40%. These conditions can decrease hatchability dramatically in a very short period of time. Slant or turn the fertile eggs daily while they are being stored. Store the eggs small end down andslanted at 30-45 degrees. Putting a piece of 2" x 4" under one end of the carton or storage container and changing it to the other end daily works well. Do not store eggs for more than 10-14 days. After 14 days of storage, hatchability begins to decline significantly.

4. Just before setting the eggs, allow them to warm to room temperature (70-80°F) and remove any cracked eggs.

Four factors are of major importance in incubating eggs artificially: temperature, humidity, ventilation and turning. Of these factors, temperature is the most critical. However, humidity tends to be overlooked and causes many hatching problems. Extensive research has shown that the optimum incubator temperature is 100°F when relative humidity is 60 percent. Concentrations of oxygen should be above 20 percent, carbon dioxide should be below 0.5 percent, and air movement past the egg should be 12 cubic feet per minute.

There are two types of incubators commonly used:

1. Forced-air incubators which have a built in fan to circulate the air.

2. Still-air incubators which have no fans, so the air is allowed to stratify.

The advantage of the forced-air incubator is that it is easier to maintain humidity at a constant level because of air circulation. Still air incubators are smaller and air flow is harder to manage ... There can be as much as a 5° difference in temperature from the top to the bottom of some of the still-air incubators. It is very easy to overheat the eggs in still-air incubators and difficult to maintain proper humidity ... To obtain reliable readings, the bulb of the thermometer should be at the same height as the tops of the eggs and away from the source of heat.

Mortality is seen if the temperature drops below 96°F or rises above 103°F for a number of hours. If the temperature stays at either extreme for several days, the eggs may not hatch. Overheating is more critical than underheating. Running the incubator at 105°F for 15 minutes will seriously affect the embryos, while running it at 95° for 3 or 4 hours will only slow the chick s metabolic rate.

An incubator should be operated in a location free from drafts and direct sunlight. An incubator should also be operated for several hours with water placed in a pan to stabilize its internal atmosphere before fertile eggs are set. Do not adjust the heat upward during the first 48 hours after eggs are set. This practice cooks many eggs. The eggs will take time to warm to incubator temperature and many times in small incubators the incubator temperature will drop below 98°F for the first 6-8 hours or until the egg warms to 99°-100°F.

If you experience a power failure, do not scrap the hatch. Most of the time the hatch can be saved. The key is to keep the eggs as warm as possible until the power returns. This can be done by placing a large cardboard box or blankets over the top of small incubators for additional insulation. To warm the eggs, place candles in jars, light them and place the jars under the box that covers the incubator. Be careful not to put any flammable material closer than a foot from the top of the candles. The heat from the candles can easily keep the eggs above 90°F until the power returns.

Embryos have survived at temperatures below 90°F for up to 18 hours. You should continue to incubate the eggs after the outage; then candle them 4 to 6 days later to check for further development or signs of life. If, after 6 days,

you do not see life or development in any of the eggs, then terminate incubation. Most of the time, a power outage will delay hatching by a few days and decrease the hatchability to 40-50 percent.

The relative humidity of the air within an incubator should be about 60 percent. During the last 3 days (the hatching period) the relative humidity should be nearer 65-70 percent. (Too much moisture in the incubator prevents normal evaporation and results in a decreased hatch, but excessive moisture is seldom a problem in small incubators.) Too little moisture results in excessive evaporation, causing chicks to stick to the shell, remain in the pipped shells, and sometimes hatch crippled. The relative humidity in the incubator can also be varied by changing the size of the water pan or by putting a sponge in the pan to increase the evaporative surface. The pan should be checked regularly while the incubator is in use to be sure that there is always an adequate amount of water. Adding additional water pans to small still-air incubators is also helpful to increase humidity.

During the hatching period, the humidity in the incubator may be increased by using an atomizer to spray a small amount of water into the ventilating holes. (This is especially helpful when duck or goose eggs are hatching.)

Whenever you add water to an incubator, it should be about the same temperature as the incubator so you do not stress the eggs or the incubator. A good test is to add water just warm to the touch. Using a wet-bulb thermometer is also a good way for determining relative humidity. The wet-bulb thermometer measures the evaporative cooling effect. If the wet and dry bulb read the same temperature, you would have 100 percent humidity. The greater the evaporation taking place, the lower the temperature reading on the wet-bulb thermometer and the larger the spread will be between the wet- and dry-bulb readings.

To make a wet-bulb thermometer, just add a cotton wick to the end of a thermometer. Then place the tail of the wick in water. The cotton then absorbs the water. As the water evaporates from the cotton it causes a cooling effect on the thermometer.

The table below (Relative Humidity) will enable you to calculate relative humidity using readings from a wet-bulb thermometer and the incubator thermometer.

Incubator Temperature	Wet Bulb Readings					
100°F	81.3	83.3	85.3	87.3	89	90.7
101°F	82.2	84.2	86.2	88.2	90	91.7
102°F	83	85	87	89	91	92.7
Percent Relative Humidity	45%	50%	55%	60%	65%	70%

The best hatching results are obtained with normal atmospheric air, which usually contains 20-21 percent oxygen. It is difficult to provide too much oxygen, but a deficiency is possible. Make sure that the ventilation holes are adjusted to allow a normal exchange of air. This is critical on home-made incubators. It is possible to suffocate the eggs and chicks in an air-tight container. However, excessive ventilation removes humidity and makes it difficult to heat incubators properly.

Eggs set on their sides must be rotated 1/2 turn at least 3 times daily. Eggs set with the air cell end up should be tilted in the opposite direction 3 times daily. This keeps the embryo centered in the egg and prevents it from sticking to the shell membrane. If hand turning, to insure proper turning, mark each side of the egg with a pencil. Put an 'x' on one side and an 'o' on the opposite side. Stop turning the eggs for the last three (3) days of the incubation cycle (at 18 days for chickens, 25 days for waterfowl, etc.) and do not open the incubator until the hatch is completed to insure that a desirable hatching humidity is maintained.

Do not help the chicks from the shell at hatching time. If it doesn't hatch, there is usually a good reason. Also, prematurely helping the chick hatch could cripple or infect the chick. Humidity is critical at hatching time. Don't allow your curiosity to damage your hatch.

As soon as the chicks are dry and fluffy or 6 to 12 hours after hatching, remove the chicks from the incubator. It is good practice to remove all the chicks at once and destroy any late hatching eggs.

Hatching time can be hereditary and you can control the uniformity of hatching by culling late hatchers. If you keep every chick which hatches late, in a few years each hatch could last 4 days or longer.

No matter what type of incubation you use, it is important that you thoroughly clean and disinfect the incubator before and after you use it. It is just as important that the incubation room and egg storage area are kept equally clean. The lack of sanitation will decrease hatchability.

Immediately after each hatch, thoroughly clean and disinfect all hatching trays, water pans and the floor of the hatcher. Scrape off all egg shells and adhering dirt. Wipe clean surfaces thoroughly with a cloth dampened in quaternary ammonium, chlorox or other disinfectant solution.

One of the miracles of nature is the transformation of the egg into the chick. In a brief three weeks of incubation, a fully developed chick grows from a single cell and emerges from a seemingly lifeless egg.

Mc Elroy describes it as a miracle when the eggs hatch, and with all due respect to the wonders of life, we would remark that it is no less a profound miracle that the eggs should hatch with so many things that can go wrong. At any rate, it certainly is a profound event whenever a human being manages to do what comes so naturally to mother birds and reptiles. Our advice to farmers is to leave it to the experts: animals and enthusiastic breeders.

Incubating Without Electricity

Incubating eggs is much easier with electricity and thermostats. However, it is possible to incubate with candles, and fires of all kinds. But these require even more attention to ensure that the temperature is regular.

Duration of Incubation

The duration of incubation varies by species. A comparison of birds illustrates that there can be a great difference in the time and conditions required by species, and further discussion on reptiles becomes unnecessary. Each species has its own requirements, and these can be discovered by studying how the animals make their nests and care for their eggs: bring thermometers, humidity gauges and other important scientific measurement tools when doing so.

Incubation Periods (species and days required to hatch)			
Bobwhite Quail	23 - 24	Guinea	27 - 28
Chicken	21	Muscovy Duck	35
Chukar Partridge	23 - 24	Pheasants	24 - 26
Coturnix Quail	16 - 18	Ostrich	42
Ducks	28	Swan	35
Geese	28 - 33	Turkey	28

Beginning with Live Chickens and Geese

By far, the most affordable and quickest method of increasing a flock is ordering by overnight mail from a breeder. It is a good way to obtain quality stock from which to build your flock. It is safe and reliable, and for the farmer quite practical and financially responsible.

Chickens and geese will require different care as they grow older, but all birds that are shipped by mail require the same initial care. As far as we can discern, no reptiles are yet available by mail-order. Animals must be bought from dealers, who are usually more than happy to assist you.

The first step towards successfully receiving your birds is to notify the Postmaster or private Mail Director that you expect a shipment of live birds. Ask the Postmaster or Mail Director to set the box (they will know which one it is – it is the one that chirps or peeps!) in a warm place and call you IMMEDIATELY. You will pick them up at the post office and do not want to wait for home delivery (if home delivery is an option).

Our Postmaster and Mail Director have remarked that they enjoy holding baby birds for us more than bees, but that both are terrifying. Assure them that if directions are followed, the baby birds will be fine.

The company that ships the birds will tell you when they expect the package to arrive. Make yourself available to care for the young birds all day and prepare the brooding area ahead of time, ensuring you have water, food and heat ready. Speed is essential to success! Traveling is difficult for baby birds and the sooner that they are home and not traveling, the better.

As soon as the birds are brought into their brooder, gently dip their beaks into the water and the food to show them where they are.

Geese are herbivores, and will require a supply of green stuff. Other farmers claim that they especially enjoy clover sprouts, but we have undertaken trials and learned that they prefer everything. Even metal bolts (on accident, a bolt came off after a baby goose worked at loose for several hours. This was devoured with gusto, with no harm to the animal). Geese do well with grain feeds as well, but do require some greens. We had a neighbor who, out of anger, fed our geese rope, nails, and paint and the unfortunate birds lived a long, healthy life with no apparent discomfort.

Chickens are omnivores and especially eat grains, but baby chicks will do best with ground grains small enough to swallow, or else non-dairy flat breads that are easy for them to peck. Chickens are too smart to be fed the trash that geese will eat willingly.

While feed will be discussed more later, chicks and goslings need less calcium than adult birds and an adult ration of calcium will hurt them.

Transporting Immature and Adult Birds

If you are transporting the birds yourself from the breeder, ensure that they get adequate heat, water and food on the journey. Baby birds should be kept very warm and sheltered: avoid shaking, bumping and jostling them. Though they obtained enough nutrition from their yolks before hatching to survive a day without food or water, water and food should be offered every half hour to every hour: the vehicle should be stopped for this. It is likely they will not take food, we suggest fortified water.

When transporting adult birds, they should be fed and watered every hour to two hours, and while considerations should be made that they are not too cold or hot or jostled, they are considerably hardier than chicks. We suggest a cage for the adult birds that a cloth or tarp can be tied to protect them from dust, wind, and other hazards of travel. Secure the cage well to the vehicle. Chicks we usually carry in a box on our laps, or directly in our hands. Be prepared for messes! Traveling birds love fortified water. We suggest also treats for the larger birds. If you are familiar with their favorite food, bring it along.

Receiving Live Baby Birds

When the birds arrive, promptly pick them up at the post office and take them home. Unpackage the birds and place them into the brooder. As you do so, inspect each bird for health problems or death. Separate out the ones that are less healthy and put them in another brooder.

Healthy or ill, provide a basin of water for the first hour or so for the young birds to bathe and drink from (changing the water frequently as it gets dirty) and food. The baby birds will desire a bath as much as a drink! They are such clean animals.

Inspect the ill birds and, if it is winter, provide them with more heat: it is likely they suffered from cold during shipment. If it is summer, provide cool water: it is likely they suffered from heat. Consult a veterinary reference book for the symptoms and treat them immediately. A general precaution for disease is heat and fortified water, unless the disease is overheating. Treating the ill and injured birds immediately ensures a better survival rate.

Segregation of the ill birds will reduce the risk that they will be further injured by the healthy ones, or that they will infect the healthy ones if they become contagious. If only one bird is ill, provide it with a "friend:" it is stressful for birds (especially newly hatched birds) to be alone.

If possible, choose a male bird for a companion, even if the needy bird is also a male. The baby roosters will generally take care of their friend better than baby hens will, providing warmth, song and other comfort. While we did have one baby hen with an instinct to care for weak companions (she encouraged them under her wings), such a bird is rare. If you do have such mothering birds, segregate them from the other hens when they are mature and do your best to ensure your roosters have plenty of opportunity to mate her as this is a trait you would like to encourage and is, largely, hereditary.

To ensure ample mating opportunity, segregate the desired hen and rooster in a comfortable, well lit coop. You may wish to install a camera or a small child to observe them to see if and when the rooster has mated the hen. Depending on the birds, they may mate right away, they may not mate for days. Keep the hen isolated so that her precious egg does not become mixed up with those intended for collection and harvesting. If she does not brood the egg, you may need to. You may need to have the rooster mate her several times before she understands she is to brood the egg: she may be intelligent enough to remember that eggs are taken from her, and not have any desire to brood.

The rooster may be unwilling at first to mate her, being too upset with his captivity. Perhaps he loves another hen better. There are many things that can go wrong, which is why some farmers never attempt breeding and are content to allow nature to take her course with the flock: eventually, though environmental pressures, birds will be encouraged to breed a better mother and a better brooder.

If there are too many birds in an area, or if they are stressed, they will be less inclined to mate and brood. Make life good enough to justify bringing baby birds into the world and your adult birds will take care of the rest.

Record Keeping

Immediately begin record keeping. Some farmers tag each bird with a ring around their leg, or note the color and markings of a bird. Tracking useful information like weight, behavior, broodiness, health and diet against age and time and seasons helps make better decisions for your flock. Select your best birds for mating and your best breeds for expansion.

Whenever eggs are harvested, tally how many are harvested and from which coop. It will likely be impossible to tell which hen laid it. Harvesting frequently reduces the risk that the birds will step on and break the egg.

Do not allow birds to eat the eggs, as they may develop a liking for eggs and begin to eat their own eggs. If birds do develop a taste for eggs, give them eggs spiked with chili powder or wasabi and they will soon unlearn the bad habit.

Brooder hygiene and early medical needs

All birds (all animals for that matter) require proper hygiene. Fecal waste should be removed promptly from the floor (a grate with a collection bin underneath serves this purpose wonderfully if the collection bin is cleaned once or twice per day. If you lack such specialized equipment, provide bedding materials, such as straw, wood chips or newspapers, and change regularly), food and water should be kept in a way that the birds cannot sit in them (except the first welcome-home bath), and fresh water and food should be provided daily. Initially, and at all times of high disease risk, change the water twice or three times per day. The pen that the baby birds are kept in should be cleaned daily.

A well designed brooder has a floor that allows bird waste (feces, uneaten food, feathers, etc.) to fall through and not pollute the living area, a wide feeding and watering area so the birds don't have to wait in line (and fight for a place in line) to eat or drink and be constructed to prohibit the birds from sitting in their food or water.

This can be constructed out of wood by making a box and screening in the top and bottom (make sure that the top hinges open with a door), and suspending the box above the ground so a collection bin can catch the droppings. A brooder should be at least one foot tall. As chicks and goslings grow up, they will need more space and will demonstrate symptoms of overcrowding: you will need probably three stages of brooders per batch of chicks and goslings before they are grown up and can enter their adult coops.

It is not good to separate batches of goslings, as they become very attached to each other. It is best to brood small batches of goslings so they can all be kept in the same brooder – even when more mature.

We keep a special "training" coop for birds who have their adult feathers but are too small to mix with adult birds: when they have their adult feathers they no longer require a brooder, though they may require supplementary heating and other "babying" even in their training coop.



The brooder allows waste to fall to a catch below, the birds cannot sit in their food or in their water.

One common problem the birds may experience is constipation in the form of "pasting," or the solidification of excrement over their vent (the bird equivalent of an anus). This is the result of stress: simply clean the bird's vent in warm water and very gentle scrubbing (fluff dry with a hair dryer or a towel afterwards so that they don't catch cold!).

Make sure the bird is not cold and then segregate (with no friend) the constipated bird until the now-cleaned bird is entirely dry because their vent (now exposed by the damp and unfluffed feathers) will attract unwanted attention from the other birds, who may injure the wet bird by pecking. Their vent triggers, by its size, shape and color, the instinct for pecking at food. Pasting is not contagious, so as soon as the chick is dry it can be put back in the brooder.

Lighting

Lighting is important. The birds will do best when subjected to natural daylight rhythms. Yet the color of the walls will matter greatly. You want colors that make it hard for the birds to see blood spots on their friends: birds love to pick at red spots and white spots, because instinct guides them this way to food. It can be disastrous to have a small wound or constipation on a small bird pecked at constantly. It is wise to only use red or blue colors: these make it hard for the birds to see colors to peck at.

Population density

If the birds are particularly hostile to each other, it is probably due to resource competition. Increase the square feet per bird, the amount of feeding space and the amount of watering space to reduce competition. Birds that are not over crowded are gregarious and will band together for the common defense (against predators, cold and other stresses). All birds, though, will sometimes peck at each other to establish leadership: this is where the term "pecking order" came from.

Occasionally, you have an aggressive bird. This bird needs extra attention from people.

Geese provide secondary services and require special considerations

Geese have an advantage over chickens in that they may be trained to provide secondary services to the farm as security animals. Some breeds are better than others at this, just as some breeds of dogs provide better security services than others. Beyond patrolling all night (geese sleep periodically through the day and night) and sounding the alarm at any intruder, they can be taught to readily defend themselves, their territory and their masters (and, more importantly, not to attack friends of their masters). An enraged goose (or flock of geese) can be more terrifying than an enraged dog, and will not back down as many dogs will. Geese will not be "bought off" for treats as many dogs will. Geese can inflict as much damage as a dog can, with beak, wing and their sharp feet.

However, sometimes geese can be hazards in the garden. Unlike chickens, who are not herbivores, geese are and can damage a vegetable patch as easily as any deer if allowed. Luckily, it takes little to keep a goose out of a vegetable patch: a fence too tall for them to step over (sometimes even 1 foot tall) will usually suffice, and a normal fence is a formidable barrier to them.

We once had a batch of geese that liked to climb. They would even climb trees, as incredible as it sounds: though they could not climb vertically, if there were trees with an angled trunk, they would be up among the branches in no time (to the great terror of all the arboreal species of our forest). They would then hop and fly off, usually at the heads of their masters and visitors. It was good fun for the geese, but a bit of a nuisance for visitors. For these geese, we required a better fence. But they were highly abnormal.

Geese, generally, rarely think to fly over an obstacle: flying is for long-distance travel only.

Feathers and hair are valuable

Both chicken and goose feathers are useful insulation, make excellent fabric ornamentation, ornamental pens and other trifles. The harvesting of feathers can provide supplemental income or product for the farm, but can leave birds cold in the winter. With training, birds can be brought to suffer the pain of plucking, but this is rarely worth the labor.

Better products are gained from the coats of goats, sheep, llamas, rabbits and yaks, none of which must be slaughtered to harvest the hair: hair is cut off or brushed off, cleaned and spun.

That said, if you desire to pluck live birds, take feathers only from the underside of the bird, pull out only small pinches of feathers and down at a time, avoid tearing the bird's skin, remove only 50% of the plumage from the plucked area at any time and do not leave any bare patches.

To make wonderful feather pillows, it is necessary to sometimes enclose a pillow within a pillow so that the smaller down feathers do not escape. Adjusting the down to feather ratio is a

personal preference. For comforters, quilts, sleeping bags and clothing, to keep feathers evenly distributed, sew channels within the cloth so that it is compartmentalized. This way, if the feathers settle, they do not settle far. This sometimes makes sense for pillows as well.

Of course, washing the feathers before plucking and afterward is important.

Adopting and domesticating animals

When adopting or domesticating animals, you have none of the inconveniences of boxes. But, at the same time, you have many other inconveniences that are far more difficult to overcome. Domestication of a wild flock can take years of patience, adoption of a flock means adopting all the problems of the prior flock manager: maybe your neighbor or friend did not handle them kindly and they are scared of people, maybe they have disease, maybe they have learned bad habits (such as eating eggs), maybe they have never learned how to defend themselves against predators or have not been taken care of physically so that they cannot fly, run, find food or do any of the other things that birds need to be able to do.

When we have adopted birds in the past, we keep them penned in their coop for a week until they learn where home is. We visit them throughout the day and talk with them, touch them and introduce ourselves – and train them to come to a feeding bucket. Older birds learn new tricks with difficulty, but this trick is as easy as it is important. Locking them up with a rooster helps their learning. We train them the next week to come home before it is dark by feeding them treats before dark in their coop. Usually, everyone is home before dark and we can close them in their safe home before any coyote, fox or other predator even thinks to look for them.

Though there are many good books on raising birds, we cannot recommend highly enough *Your Chickens* or *the Chicken Health Handbook*, both of which are authored by the illustrious Gail Damerow, who is the highest authority on the subject of chicken care in particular (and other small livestock care in general).

Training production chickens

Chickens are generally very trainable birds. They can be taught complex helper behavior that brings them into the classes of work animals, but even production birds can learn basic lessons that make them easier to handle and reduces their stress when they do need to be handled or culled. Chickens respond best to positive reinforcement: as with bovines and equines, gentle handling and clear, repetitive instructions will lead to a calmer, better trained bird than rough handling and punishment for wrongly followed instructions.

When we first get our chicks, we pick each one up several times and hold it for a few seconds. It is important (but not essential) to begin training the chicks when they are very young. This allows them to become used to handling before they develop fear (a mental condition that does not develop until they are 3-4 days old). When you pick them up, scoop them gently and encourage them to step onto your hand before picking them up. Hold them securely so they feel safe, but not so tight that they think you're eating them. If they flap their wings a lot, gently but firmly place a finger over their wing joints to hold their wings down. Stroke them like you'd pet a cat or dog: they may even fall asleep on your hand!

For the next few days, pick them up at least once a day like this. More is better. If your chicks don't seem to be understanding, pick them up and set them down repeatedly without pause as they figure it out.

It will help them learn that they want you to pick them up if you carry them to a "play area" where they can enjoy themselves. Chicks (and chickens) love to play. If you provide them a small area where they can roll on the ground, flap their wings and practice flying, chase each other, eat off the ground, and perhaps even shred some newspaper or straw, they will love it. They will learn within a few days that when you come to pick them up, they might be going to the play area and will more willingly get on your hand to go there. It is a lesson they keep for life. They can stay in their play area for as little as 15 minutes to as much as several hours (make sure they have water available if they'll be out for a while): put them back as you need to, or better yet when they are becoming tired.

However long you let them play, though, be sure to check on them every once in a while. Sometimes in their play they will become violent to each other (on purpose or by accident), and a chick may be injured from it. If you hear them screeching, check if they are just playing or if one is hurting. Some chicks won't screech when hurt, so check from time to time anyway. Quick response to a chick being injured can usually keep the chick from serious injury.

Some chickens are more easily trained than others, but all can be trained. If you are having trouble training a chicken, be patient and spend more time with it. Learn what it likes and doesn't like: for example, one of our roosters did not respond well to training to be picked up, but it turned out he liked to be lifted with his feet dangling and didn't like standing on hands or arms. Some chickens have difficulty understanding that you are not trying to hurt them. Take a few minutes every day holding those chickens, stroking them until they relax. Perhaps you can provide them a bit of food in your free hand for them to enjoy while you hold them. Teach them that it is nice to be held.

Practice other skills with them when they are picked up, including getting their feet and wings examined, being carried around for a minute or two, and being carried away from their friends. This will make it easier (and less stressful for the chicken) if you ever need to examine them for illness or injury, restrain them for medical or show purposes, or need to move them from place to place and don't have a cage to transport them in.

As they grow, it may be uncomfortable to hold them on your hand because of their weight and claws. You can teach them when they are this size to stand on your forearm instead of your hand: they might even prefer this because it is sometimes easier for them to hold on that way. You can also teach them to stand on your hand while it is gloved: if they seem afraid of your glove, try a different type (leather vs. cloth) and have patience. Practice holding them so that they stand calmly on your hand, and also so that you can cradle them against your chest. You can also teach them to be picked up without stepping on your hand: grab them securely under their sides near the front of their body. The first time you hold one like this, they may be alarmed. Let them stay standing on the ground, but hold on securely until they relax. You can let them go free, or move onto the next step: lift them up from the ground, so their feet are dangling. They may struggle: if you have a good grip, you may want to continue, or you can set them back down without letting go, and let them calm down again. When you (and the chicken) are ready to be picked up fully, lift them all the way up to your chest and cradle them. You can remove your hand closest to your chest and move it for the chicken to lay down on under its body (the first few times, you may want to let them stand on that hand, like they used to, to connect the experiences in their mind).

To teach a chicken to come to you is more difficult. Some chickens are naturally friendly and inquisitive, and may come over to you when you visit them, perhaps even following you around through your chores. Most chickens will come to you if they think or know that you have a treat for them. Chicken Scratch is often sold for this at feed stores, though they also like some table scraps and brown uncooked rice. If you scatter your treat for them so they can hear it, they will learn what the sound means and will come when they hear it even if they didn't see you had it.

You might then try to train them to "voice commands." Chickens don't seem to have much recognition of the difference in words: all our words sound the same to them, just like all their words sound the same to us. However, they can learn what you are saying if you invent "words" with whistling. For example, you can teach them "no" is a shrill one note whistle. Reinforce it with a bang or other noise that makes them stop what they are doing. Once they associate the whistle and bang, they will stop when they just hear the whistle. You can use different tunes and notes to teach them other commands, too.

Where you keep your chicks for their first few weeks of life will impact how they behave when they are older. If you are able to, keep them in a main thoroughfare of your house: this will get them used to people moving around them and other movements. Then they will be less afraid of people walking around them and other movements when they are bigger. This will make it both easier for you to catch and handle them, and less frightening to the chickens too. Don't try to walk carefully around their cage: instead, walk normally, talk, sweep, and sometimes even use the top of their cage for a table. A week or two of this exposure at a young age will help your chickens be less afraid of unknown movements and objects for their whole life.

Chickens are not just for the farm, but ideal for the urban home

More and more people these days are looking for ways to stretch their grocery budget, support local industry especially local foods, and be environmentally friendly. A great way to accomplish all these goals is to get a chicken (or several chickens!).

Most cities allow residents to keep at least one chicken. One hen will lay 5-10 eggs per week, depending on her age, breed, and time of year. For just cents a day in chicken feed you can get lots of fresh eggs to feed your family, and can sell any extras! Chickens love to eat food scraps, keeping more trash from landfills and minimizing or eliminating your needs for composting (which is especially beneficial if your city or HOA prohibits composting). Chickens require minimal shelter, equipment, and other investments for a return on many years of eggs. Plus, fresh eggs taste better!

Before you begin, check with your local government to learn if there are any restrictions to the number and gender of chickens you can keep, and any other laws regarding keeping your flock.

If local laws allow it, you'll also need to decide whether you want to keep roosters. Hens do not need a rooster to be able to lay eggs. However, if you want to produce chicks, your hens will need a rooster. Roosters are also popular for competitive showing. Roosters can also be useful if you let your chickens roam where predators might be able to access them: the roosters will defend their hens against many predators. However, some people do not like the loud crowing of roosters. Roosters may also injure their hens at breeding time; even minor injury such as pulled feathers may not be desirable if you plan on showing your hens. If you do get roosters, you will need to make sure you don't have too many per hen, or else they will fight a lot over the hens. Generally, it is ideal to keep about one rooster per 7 to 10 hens.

Veterinary care for birds is still developing, basic care the farmer can undertake

When raising birds, as with any animal, it is a good idea to become familiar with basic health care. This is especially important when raising chickens (or other poultry or waterbirds) because very few vets are trained to be familiar with such critters. Even livestock vets don't tend to know much about chickens!

The most important thing you can do to care for a sick chicken is to be able to recognize that it is sick in the first place. This is sometimes very obvious, but many times chickens will begin to display only minor signs of illness when they are just coming down with something and can be treated before it is too late. Observe your healthy chickens every day so that you can recognize when sometime is different. Pick them up and feel them over, too, so you'll know what's normal if something changes.

Some important things to look for include overall composure (is the chicken holding its head, body, wings, etc in a normal position?), behavior (is the chicken alert? happy? social?), sounds (is it breathing normally? is it talking normally?), temperature (skin temperature is usually a good enough indicator: you don't need to use a rectal thermometer unless it seems like something is otherwise wrong), feces (consistency, frequency, and color), and egg production (if your hen changes her laying behavior, frequency, or appearance of the egg, something may be wrong).

The easiest problem to notice is typically a wound; these are also some of the easiest problems to treat. First, as much as possible, isolate the injured chicken. Examine the wound: is it superficial or deep? Is it on a critical place (such as the vent)? Can the chicken stand and flap normally? Clean off the wound, apply some antibiotic (such as Neosporin – it now comes in a spray applicator for easy use on chickens too), and keep the chicken in a clean environment while it heals. If it's a very serious wound, you may need to take it to the vet for stitches: even non-chicken vets can competently give stitches to birds too. If possible, your chicken will like it best if it can still see and talk to other chickens, such as by keeping it in a cage in the coop area.

If you suspect your chicken has a broken bone, assess if it can still function normally while the bone heals itself. It is impossible to cast a chicken, but splints may be recommended in certain instances. If a splint seems necessary, have a vet advise you: putting one on incorrectly can make the problem worse.

If, for some reason, your injured chicken needs to be restrained for a longer time and/or cannot stand, you can improvise a sling by using a (clean) basketball net suspended with clips in a cage. Make sure that the chicken resting in the net is not able to fall out when wiggling, won't lose circulation to any limbs, and can reach food and water.

If your chicken is sick, the most important thing is early detection. The sooner you notice a problem, the easier and better it can be corrected. Isolate the chicken both for its own health and for the other chickens: if the problem is microbial (bacteria, virus, etc) you don't want the other chickens catching it. Clean the chicken's old home thoroughly to keep other chickens from picking it up, and to prevent reinfection when the sick chicken heals and is reintroduced. Clean it's "infirmary" often to prevent reinfection or secondary infection.

Most chicken illnesses are bacterial, and can be treated with a broad spectrum antibiotic such as tetracycline. Most livestock feed and supply stores carry such medications designed for chickens. Usually, it comes in a powder form that is mixed with water. To use this, add about 1 teaspoon per 5 quarts of water. Remix the water/antibiotic every day so that it stays effective. Be sure that when you dispose of unused antibiotic water that you don't pour it in a septic system nor

apply it to someone's food (especially not your own garden). If your chicken needs antibiotic for more than 5 days, stop for a day every 5 days to allow its native flora (the bacteria it needs in its gut to survive) to recover. You may want to allow it to lick a few drops of yogurt too, as a probiotic. Once your chicken looks healthy again, continue the antibiotic treatment for another few days to make sure that the infection is well gone: otherwise you risk the chicken developing a resistant strain of bacteria and that if it gets sick again it wouldn't be able to be treated with antibiotic.

Make sure that your sick chicken is eating and drinking enough. If it starts to look dehydrated, put a little salt in the water. If your chicken is not eating well and is weak, put some honey in the water (be sure to change it frequently or it will ferment). You can also squirt a bit of baby food (such as strained peas or carrots) with a needle-less syringe onto the chicken's tongue.

Special notes on goats, rabbits and llamas

Goats, excellent producers of dairy, mohair, cashmere and horns (which can be decorative, used as drinking cups, as musical instruments or for ceremonial purposes in many religions) are also raised for meat and leather. Rabbits are raised as goats are, but do not produce dairy, mohair or horns. However similar they are to other domesticated animals (especially equines, bovines and birds), several notes should be made on goats and rabbits. Llamas are very much like goats, but do not produce horns or dairy.

All three produce high quality fiber: their hair is so soft! This may be spun into valuable yarn or sold to those who will spin it themselves. It can also be used to stuff pillows, jackets, blankets and other cloth in the form of insulation.

Rabbits will digest their food twice, eating their feces. This is normal behavior and does not indicate any malnutrition. It is difficult to train work rabbits, and difficult to train rabbits period. They usually, as a result, require close penning. If you desire to graze them on pasture, construct a mobile pasture on wheels as previously discussed in regard to chickens. They can be trained to accept being picked up, and when trained in this way can be pastured in a permanently or semi-permanently fenced area.

Goats and llamas can also be trained for draft labor, and can carry both packs and pull carts.

Both can have their hair harvested without slaughter through a process of shearing and/or combing.

As with any domestic livestock, beware of those plants which may be poisonous to your animals, house them with consideration to their needs for shelter (as you would house your favorite ox or workhorse, consider housing your goats, rabbits and llamas – especially in regard to those animals that you train as work animals)

Special notes on turtles and tortoises

Turtles and tortoises produce not only high quality eggs, but also luxury meats, decorative shells (which can be used in the making of musical instruments, as ornamentation, in jewelry, etc.) and, in many places, baby turtles and tortoises for domestic pets. Their fat is used in cosmetics. Turtles and tortoises also are used in many traditional medicines. As such, they present a very lucrative prospect to a farmer who wants to undertake an unusual animal husbandry. They are easy to care for and breed and are in many respects easier than birds. They require some protection against predators.

Aquatic turtles have webbed toes and spend the majority of their time in water. Aquatic turtles include basking turtles (those which warm themselves in the sun by crawling out onto logs or rocks) and the family Emydidae (the sliders, spotted turtles, painted turtles, cooters and map turtles). Most aquatic turtles prefer fresh water, but there are a few saline varieties as well.

Nonbasking aquatic turtles include the family Kinosternidae (mud and musk turtles), the family Trionychidae (soft shelled turtles) and the families Chelidae and Pelomedusidae (side necked turtles). These sun themselves by floating at the water's surface or in floating weeds.

Tortoises are land-bound animals of the family Testudinidae. They generally have highly domed shells. A few, though, do not. Some of the forefeet of the burrowing species are flattened and spade-like for digging.

Your animals will require food, and while some varieties are herbivores, others are omnivores and others are carnivores. Before selecting a variety for domestication, you would do well to observe what they eat in the wild (or asking their breeder), or perform taste-trials by presenting a variety of foods. However, this is not failsafe as the animal may not know what is best for them: many animals develop an unhealthy taste for unhealthy foods. After learning a variety of the foods they like, present a variety to them: a varied, balanced diet is always healthiest. Tortoises are generally herbivores, and prefer vegetables and fruit, but we have had good experience with feeding them grass. Most turtles are omnivores, enjoying the occasional worm or insect, baby mouse, fish and will also eat snails. They are a convenience to the farmer because turtles and tortoises have very similar needs to their foods, and their food animals and food plants are easily raised if not in the same pen, then nearby in rotation.

Use caution in feeding things to turtles with a lower calcium to phosphorus ratio of 2:1 (Ca:P). Thus, avoid foods high in phosphorus and low in calcium, such as grapes, bananas, mealworms, crickets and peas. Spinach should not be fed to turtles or tortoises as they do not digest oxalic acid well and this can damage their kidneys with calcium oxalate.

Sea turtles are the most commonly agriculturally domesticated species of turtle, and are typically raised for meat. However, turtles and tortoises of many varieties are farmed in the Cayman Islands, in Oklahoma and Louisiana (United States production is usually intended for export to China) and in China (where there are hundreds of farms). Much of the turtle demand is met by capturing wild animals, so the potential for agricultural profitability is great. Most wild turtle in the United States is captured in Florida. And, as the turtles and tortoises become more protected from wild harvest, this will favor agricultural production more.

Shelter for aquatic varieties requires a pond, and those that venture onto land will enjoy some low-growing bushes, logs or other hiding spots. The pond should be kept "dirty" with vegetation and twigs to increase the comfort of the turtles: this increases their ability to hide. Many turtles and tortoises enjoy burrowing into the soil periodically. If your soil is good enough for the vegetables and fruits they enjoy most, it is good enough for your animals, too: it must be soft, but not too soft! This encourages the farmer to rotate turtles and tortoises as they would snails, with a rotation of vegetables and fruits. Besides keeping the environment hygienic through tillage and planted with suitable shelters, it allows the farmer to keep the soil soft enough for the animals to enjoy. Refer to the notes on domesticating snails in the Chapter on Wild Animals for constructing pens and make accommodations for the slightly larger shelled turtles and tortoises, and you won't go wrong.

What makes turtles and tortoises different from the semi-wild snails is the occasional assistance the farmer provides in the incubation of eggs and the rearing of the young animals.

Like snails, in some places, the turtles and tortoises must be protected during the winter if they are to survive to the next year and the refrigeration of hibernating animals in controlled environments during the winter. Like snails, ensure that if the turtles and tortoises are not naturally hibernating, their digestive systems are clear of food for 1-3 weeks before hibernating.

The turtles and tortoises that require ponds have similar requirements to those of geese, but instead of a pool that slopes inwards with the deepest part in the middle, have the deepest parts of the pond on the outside with an island in the middle: if the island is on the outside, the animals when sunning themselves will be more likely to escape. The bottom of the pond should be smooth so that the animals do not scratch their shells on it (especially if you plan on selling the shells!). Check on your animals frequently to ensure that none have overturned or are otherwise in distress.

To integrate a pool into a bed for rotation with crops, simply combine two 6 foot beds and one aisle (or two aisles and 1 bed) into an 18 foot wide area. We recommend two beds and one aisles so that nearby crops will still have the advantages of tillage in the aisles. Move the soil with a plow or shovel from the outside to the middle and compact the bed or otherwise prepare it to retain water (a lining is easily removed during rotation back to crops).

Because of the value of the animals, it is advantageous to cover the pen with a screen or cloth to prevent birds from landing in it and harassing the animals. Also construct a good fence to keep out predators (bury the line 1-2 feet underground to prevent burrowers).

Some tortoises and turtles become socialized to humans and enjoy being petted and receiving attention, but they are difficult to train. We have not had success with training work turtles or tortoises. Training the animals that food will be placed at a particular spot and blowing a whistle or associating the food with some other signal helps train the animals to come when desired.

The shell and camouflage of a turtle or tortoise is its best defense, but they also can bite. Some can pull their entire bodies into their shells. Others cannot. In most cases, a turtle or tortoise relies on hiding to accomplish its protection. Ants and other predators know that a turtle or tortoise will react to a threat by withdrawing into its shell and staying still, and have adapted. Keep an eye out for animal fatality and try to understand its causes. Most turtles and tortoises bite with a sharp beak that can be quite injurious to their master. While they may not intend harm, the danger cannot be ignored and a keeper quickly learns how to hold them best: away from the mouth. Some, like snapping turtles, can only be held by the tail, as they are very agile. Others can be safely held around the middle of the shell because they are not as agile. Most animals will come to trust and know their keepers, but it still makes sense to be careful: they can bite through gloves!

Whether aquatic or terrestrial, their eggs must be laid on land. Some breed in the water, others breed on land. Providing a good environment for mating and nesting is important: the turtles and tortoises will take care of the rest. You can either leave the eggs in the soil to mature, or withdraw them to incubate them. If you do incubate them, do not rotate the eggs. Keep them warm (77 to 86 degrees Fahrenheit, depending on the species – every species is very unique) and of a suitable humidity. The best bet is to domesticate local tortoises and turtles, and allow nature to take its course, otherwise, familiarize yourself with the specific species you are attempting to breed. Every species of tortoise and turtle produces valuable food, medicine, shells and companionship. There are many qualified books on the subject, many pet stores willing to teach you, and plenty of University Extension Service agents available for questions on herpetology. Additionally, you may contact or join your local turtle or tortoise club or society. But the sheer number of species does not allow for a detailed examination into the temperature requirements for each one.

It is important to help each hatchling, whether you incubate them or not, find food and shelter and water, and help them maintain ideal temperature. Because of the value of each turtle or

tortoise, each baby is important! Unlike baby snails, the death of one turtle or tortoise represents a significant potential revenue (even if it is a very little cost). And, if they are to be sold as pets, it is important to help them learn to trust and socialize with humans! Turtles and tortoises can live to be more than 20 years old, and their first months and years are very important in forming an understanding and trust of their human masters. Even if they are to be used for egg production or breeding, you still want to build as much of a relationship with each animal as possible while it is young – you'll be working with that individual a long time.

Formulating animal feeds: an example of chicken feed

By referring to the nutritional requirements of the various species of animals that are typically raised, or by coming to learn of the specific requirements of an unstandard animal, the farmer is able to formulate a feed that adequately meets the requirements of their animals.

While the complex interaction of the numerous vitamins and minerals an animal requires only now beginning to be understood, it is possible at this point to emphasize (besides consultation with a veterinarian) that a balanced diet be presented to the animals, especially if they are not allowed to graze on pasture. For example, an imbalance of calcium and phosphorus (which, in geese especially, an imbalance is as bad as malnutrition or overnutrition – geese require a ratio range of 1:1 to 1:1.5 P:Ca when immature and 1:3.5 to 1:4.25 P:Ca when laying) is nearly impossible when fed a pasture that has many different plants to choose from – or even just one plant to choose from. When feeding hay or grains to animals without pasture, the farmer must be attentive to their feed formula.

When grazing, a farmer will sometimes supplement feed to the pasture for extra energy. Then, the necessity is not so much in providing a balanced diet, but in providing extra calories. However, such a farmer might also supplement vitamins and minerals (either in the grain supplements or by way of a multivitamin powder sprinkled in the water or on the grain) to ensure adequate nutrition.

Why should a farmer who is in doubt provide multiple vitamins and minerals? By providing the animal enough vitamins and minerals, they are able to alter their food in their guts so that they do not get an imbalance: for example if too much calcium is given, they can more easily excrete it from their blood to regain a proper balance of P:Ca.

Supplementing protein is also undertaken, with as much frequency as calorie supplementation. Provide balanced proteins – there are many amino acids! – as you would a balanced vitamin/mineral mix for best results. This means providing at least two different sources of protein (in example, sanfoin and oats, or oats and alfalfa, etc.). Every living creature has nearly every amino acid in their tissues and providing two different species as food allows a more balanced protein than one alone.

Calculating the cost of the feed requires multiplying the cost per pound of each ingredient by its relative proportion. In example, a feed of 50% Oats ($1 per pound), 25% Sanfoin ($0.75 per pound) and 25% wheat ($1.25 per pound) would cost (50% x $1)+(25% x $0.75)+(25% x $1.25) = $1 per pound.

We have sold an excellent feed and will share our recipe here. It was designed for egg and milk producing animals (as their nutritional requirements were similar) with the intention of supplementing a hay, straw or pasture diet. Two versions existed, one with a microscopic (but very potent) quantity of vitamin and mineral supplementation (0.25% by weight) and one without. We blended ingredients for palatability and for nutrition. It was very popular! Prices are from 2008.

Sanfoin Seed ($3 per pound)	=	20%
Barley ($0.26 per pound)	=	20%
Rye ($0.53 per pound)	=	10%
Flax ($0.08 per pound)	=	20%
Oats ($0.30 per pound)	=	10%
Safflower ($0.61 per pound)	=	10%
Sunflower ($1.42 per pound)	=	10%
Vitamin and Mineral (optional) ($1.04 per pound)	=	0.25%

Price per pound = $0.95 per pound natural, $0.96 per pound fortified

We were required to have the feed tested for nutrient content, but it was unnecessary as we knew the nutritional value of each ingredient. If sunflower seeds have 584 kcals per kg, and are 10% of the total weight of our feed, it is easy to see that our feed would gain 58.4 kcals per kg from the sunflowers alone (10% x 584 = 58.4). The safflower was included because, in taste test trials, it was most palatable to most animals.

	Natural	Fortified
Dry Matter	92%	92%
Moisture	8%	8%
Macronutrients		
Calories (kcalME/kg)	4987	4987
Crude Protein	20.00%	20.00%
Fat	31.04%	31.04%
Crude Fiber	9.40%	9.40%
ADF	15.60%	15.60%
NDF	32.40%	32.40%
Minerals		
Calcium (Ca)	0.28%	0.28%
Phosphorus (P)	0.45%	0.45%
Iron (Fe), ppm	115	12615
Zinc(Zn), ppm	35	40035
Magnesium (Mg), ppm	2000	2000
Manganese (Mn), ppm	32	20032
Copper (Cu), ppm	17	17
Selenium (Se), ppm	0.4	120.4
Potassium (K)	0.63%	0.63%
Cobalt (Co), ppm	< 0.5	400
Sulfur (S)	0.14%	4.14%
Iodine, ppm	unknown	500
Vitamins		
Vitamin A, IU / kg	< 220	4989600
Vitamin E, IU / kg	74	11300
Vitamin D3 IU / kg	unknown	1197504

The label demonstrates the minimum known. For example, though there might be some Vitamin D3 in the mix, we did not have it tested so we do not know. We write unknown on the label. When we add in D3, we know we are adding in 1,197,504 IU and put that down, but cannot know if there is more than that in the feed since no base (unfortified) amount was measured.

The whole grains have more nutrition than polished grains because the seed has most of its vitamin and mineral content in the hull. Eating whole grains is smart not only for people, but for other animals as well! The grain was, for baby animals whose teeth (or beaks) and stomachs had not yet adjusted to adult foods yet, ground up or crushed to make ingestion and digestion easier: some baby birds couldn't eat a whole barley if they wanted to! The baby animals, of course, required less calcium and for adult milkers and layers, we offered additional supplementation of calcium for a cent more per pound.

We priced our feeds high enough to account for transportation and spoilage, the wear and tear on our grinders so that we could replace or repair them when they broke, theft and other

disasters. In the end, we were able to sell at a price that was much less than our competitors but still worthwhile to us.

Selling supplemental feed is difficult to those farmers used to using only straight feeds. Many feeds include fillers so that the farmer need not do math to learn how much to supplement their animals. We provided a measuring cup to our customers so they could scoop the right amount, charts that explained how much weight of the feed to provide to their animals, and other helpful aids. These helped. Demonstrations helped more. With our supplementation feed and our straw, farmers stood to save sometimes 25% on their feed costs (straw is a more affordable filler than the other things used by our competitors). But, mixing our own saved us many times more per pound than buying, and it makes sense for any enterprising farmer to make their own animal feeds to reduce the costs of their feed – a key component to the overall cost of animal production.

CHAPTER TWENTY-SIX: OF BEES

Bee stings can be deadly, whether stung once or a thousand times

Whether you get stung once or a hundred times, bees can be deadly animals. Some people are allergic to the stings of bees, and a single sting will kill them. Some people have been killed when stung dozens or hundreds or thousands of times by a hive they angered. One well placed stinger can seriously damage an eye, ear, nose, finger or even close off an airway. Bees demand respect, and as when dealing with a particularly ferocious snapper turtle or any other dangerous or deadly creature, extraordinary caution should be employed.

That said, many bees are gentle and social, and will let you or even visiting children pet them (the children always remark that the bees are quite fuzzy)! Do not fear the bees, but do respect that, despite their size, they are quite capable of killing you. If you are unsure of whether you are allergic to bees, ask your doctor to perform a simple test! Those who are allergic to bees should not work with them, and should carry with them medicine for the allergic reaction that will follow a sting.

If stung, scrape off the stinger, do not pinch or pull it off if you do not want to squeeze more poison into your body.

Bees that smell a stinger will be more apt to sting you. Wash your clothes very well if you get stung – you don't want that angry smell on you.

Though you may tuck your pants into your socks and wear protective clothing, bees might still get into your clothes. Do not be bashful: if this occurs, take off your clothes. It is the age-old right of beekeepers to strip naked and run through the fields in liberated panic and though your neighbors will be amused and will never tire of reminding you of your adventure, you don't want bee stings, especially not in *some* places.

The reaction to and pain of bee stings grows less over time. We rarely use any protective clothing more than a mask and gloves. If you are careful, you will never get stung. Often.

History of beekeeping

In antiquity, humans were at best bee hunters, locating wild bees and then (carefully) pillaging the hive of honey. Then, according to historians and oral traditions, rudimentary clothes were invented to protect the bee hunter from stings. In many places, this is still how honey is obtained. Next were invented specialized tools to open the tree trunk or other hollow in which the bees had built their nest. Only then, upon being able to see (free of the harassment of the bees thanks to the protective clothes) the entire structure of the hive (thanks to the new tools) did people begin to think about building the bees a house and domesticating them.

Bees were first domesticated in the Mediterranean, though some dispute is had as to whether they were first domesticated in ancient Spain or Crete. Bees were domesticated by 15,000 BC. It is known with certainty that once they were domesticated, the surplus of bee products (honey, wax and propolis) inspired others to inquire how the wise farmers of Spain or Crete had so much honey, wax and propolis to sell.

The first agricultural beehives were simply hollowed out logs. When the beekeeper wanted the honey, they prepared another log and destroyed the first one (wearing, of course, the protective clothing so necessary to this task). This form of beekeeping persists even today. In America, it was introduced in the 19th Century when the United States colonists settling the West had no access to complex wood working equipment but did have access to bees.

From the start, the partnership between bees and humanity has been one of shelter provision. If a human provides bees with a better home than they would find in the wild (by providing protection against elements and adequate and expanding living quarters), wild bees will not only come to live in the human-made hive, but will stay.

The Egyptians improved upon the log method by 2,600 BC by developing a hive that did not need to be destroyed for harvest. Both the bees and beekeepers appreciated this so much that it became standardized among all beekeepers but those most dedicated to ancient and outmoded techniques.

To do this, the Egyptians made hives out of clay. Their hives resembled the logs they replaced. Brooding and rearing took place near the entrance and honey was stored in the back (just as today, brooding and rearing takes place near the entrance at the bottom and the honey is stored on top). These clay logs were sturdy enough that the beekeepers could put them on boats and take them up and down the Nile as the seasons changed so their bees would always have pasture. It is likely that there were as many accidents in transportation as there are today when hives are carried in automobile trucks thousands of miles to their seasonal pastures. Then, the transporters likely wore protective clothing. These days, most truckers who haul bees do not. But such is progress.

Some efforts were taken by Aristotle to discover how to farm bees better, but not having a mind for the practical application of his logical inquiry, all he was able to do was acquire knowledge on the life and habits of bees – and very useful information that was, too!

When the Romans took interest in beekeeping by the 100 AD, they relied heavily upon the observations of Aristotle. The finest minds of the Empire set themselves the task of improving upon the Egyptian method. Though Virgil offers his usual bad poetry disguised thinly by bad advice (when he used the poetic metaphor of bees breeding in the carcass of a dead ox, Virgil was taken literally for thousands of years afterward by Europeans with no sense of art or humor), Varro, Columella and Hyginus did undertake trials to improve the method of their African neighbors.

The Romans believed that when their chief god Jupiter was born, it was the bees that adopted him and raised him into his adulthood. As the fostermothers of the king of the gods, bees were in many ways sacred creatures. It was believed that the queen who adopted Jupiter was named Melissa, and it was her who allowed honey to become the food of the gods. The bees gave to Juno their honey to continue feeding her husband, Jupiter, with. Juno gave to her favorite daughter the task of bringing the honey to the gods.

The Romans (thanks to Aristotle) understood that there were various castes of bees (workers, queens and drones), and that bees undertook various jobs within the hive. However, through their own experience they discovered that bees are terrified of smoke and will gorge themselves on honey (rendering them quite docile) or flee if they think their hive is on fire. The beekeeper (still wearing protective clothes) could then remove honey, wax and propolis from the rear of the hive easier.

The Romans used dry cow manure to create smoke and put it in a pot that had a spout at two ends. The beekeeper would blow air into one end and out would come smoke from the other. This method far exceeded that of cymbals (banging them to scare the bees away) but made the honey taste like cow manure. It was not until recently that people considered using cotton, tobacco

or other better-smelling stuff to smoke out the bees. The Romans also invented a specialized knife (not much different from the beekeeper's tool of today) that allowed the beekeeper (without changing tools) to pry out frames of comb from the hive, scrape away propolis and otherwise undertake the work required in the field. Columella, as usual, provides excellent advice on beekeeping. He describes the various breeds of bees and which yield the best honey, which are most docile and which are easiest to transport.

The bees Columella recommends are now currently known as "Italian Bees," and are still the preferred breed of bees. Columella says that with good care, a colony can live for decades. Columella was also aware that bees HATE wool and sheep. To this day, it is an error seldom made for a human to wear any clothing made of wool when near a hive. Bees will attack wool on sight (or rather, smell) and will not cease until the woolly creature is destroyed or has fled. The Romans and Greeks had many colorful stories to explain this antipathy, and while more entertaining than the modern theories involving hormones, they are no more accurate. While it is still unknown why bees hate wool, it is certain they do, so don't wear any!

Columella also noticed that the pasture the bees are fed upon impacts the flavor of the honey, recommending thyme, savory, marjoram, rosemary, trefoil, pines (bees will eat the sap), dwarf oaks, ivy, jujubes, tamarisks, almonds, peaches, pears, and other fruit bearing trees for bee pasture. In a pinch, terebinths, mastic trees and linden trees are also good pasture, as are wildflowers, and agricultural flowers (especially crocus). He recommends using some of the herbs to flavor the wax and honey itself to improve its value, and condemns what is valued today the most valuable (woodland honey) as being worthless to the markets of 100 AD, calling it "dirty." Indeed, woodland honey does look "dirty," for it is dark honey: this dark honey today is the most prized of all honey, the honeys that are bright and yellow are the least valuable.

He also advises putting the bees away from the latrines because they will become unsanitary and the honey will pick up the smell of the toilets. Good advice from a smart man.

Columella goes on to describe the various methods of providing water to bees, of protecting them against theft from people, the use of wooden bee hives to replace the clay ones of Egypt. In short, he describes most of what is called "modern beekeeping," and may be accurately described as the father of modern beekeeping – if not only its first commentator.

Bees were obtained and traded in Roman times much the way they are traded and obtained now. You can get wild bees by providing good homes and hoping that a swarm will see it, you can buy queens and bees by the pound (with 4000 bees to the pound), you can breed your bees, you can buy them in the hive...

His method of hunting down wild bees is ingenious. He soaks a red string in sugar or prepares other bait and, when the bees come to it, he simply follows them home. When there (wearing his protective clothes), he grabs the queen and takes her and her swarming attendants back to his hives. There is no good reason that this technique is not widely used today except that there are many bees available at affordable prices that are less difficult to obtain. Through the modern mail-order system, the bees come straight to your front door in a box!

Columella's method of handling swarms is unique, too. When a colony was about to swarm he decided whether he needed another colony or not. If he did not, he simply added on space to the hive and the bees canceled their swarm or at least reduced the number of exiting bees (they now had enough space that they didn't need to divide their colony). If he did and he had hives on hand, he simply carried the swarm to the new hive. But if he had no hive on hand? He fed them sugar water and threw dust in their hive and, while they busied themselves cleaning up the mess, he bought himself hours in which to make a temporary hive.

If his various hives began fighting, he quelled the quarrel by throwing dust or sugar at their hives, and if that didn't work, he killed the leaders of the aggressors until the bees believed themselves to be defeated by their enemy (not perceiving the large human who was actually killing their best and bravest heroines) and were forced to retire from the field.

Columella avoids the poetic temptation of Virgil and does not attempt to demonstrate a parallel between human civil wars and the civil wars of bees, nor does he succumb to the temptation to comment on the nature of war in general. His words are poetic enough, when he warns that whole nations of bees may be destroyed by war, but if, through sugar, good feelings can be inspired among the leaders of the bees, peace continues and no blood is shed.

To capture swarms, he recommends dipping your hand in sugar water or juice so the bees will be inclined to come to you. This practice is still undertaken today.

In the years after Columella, no new developments to the technology or technique of beekeeping were undertaken. With Europe's economy shattered during the fall of the Roman Empire, people could barely afford bread let alone honey. With no demand, farmers took their efforts and put them elsewhere.

During the Renaissance when Europe had more money, few (in fact no) scientists dedicated themselves to the development of agriculture. During the Scientific Enlightenment, only Jethro Tull dedicated himself to the improvement of agriculture, but he did not raise bees.

By the 19th Century, beekeeping was becoming more popular in England, and in 1798 the Western Apiarian Society of Exeter offered prizes to farmers to promote the maximum amount of honey with the minimum destruction of bees.

In 1819, Robert Kerr of Stewarton built the precursor to the modern hive, with honey depositories on top and brooding areas below. However, the bees were still not using the space inside their hive well, and were forced to spend valuable energy building walls and support structures. So, in 1851 the Reverend Lorenzo Lorraine Lnagstroth studied the structures the bees built and emulated them. He discovered that honeybees will attempt to make spaces between combs approximately 3/8 inch wide. So, he built a hive with interchangeable, moveable "leaves" (an invention of the Swiss naturalist, Huber) that were spaced 3/8 inch apart...and had a remarkably higher yield of honey for it!

The modern smoker was invented in 1874, and in 1857 bees wax that had been stamped with hexagons was invented: the hexagons saved the bees most of the laborious work of spacing and shaping their cells and improved honey production greatly. And now, the beekeeper could help the colony decide whether to produce honey combs or breeding combs (they are of different size, and the beekeeper who wants honey will put in stamped wax of the correct, smaller size). In the 1920's were invented various screens to prevent eggs from being laid in honeycomb (large enough to let workers through but small enough to prevent the queen).

The centrifugal honey extruder was invented by the son of Major Franz von Hruschka who noticed that when his son was given a piece of honeycomb in a basket, he would twirl the basket around and honey would come out the bottom. The process was refined until the 1920's when the modern centrifuge was invented.

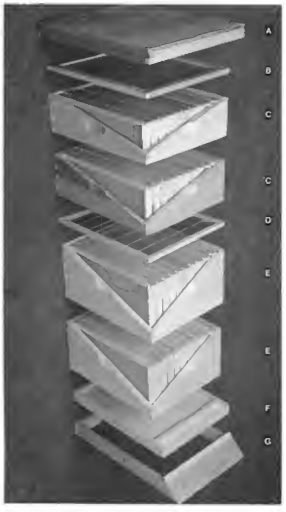
Today, humanity can enjoy cheap honey because of the great advances made in the care of bees.

Beginning production: the components of the hive and the tools of the trade

Whether you live in an apartment or a house, it's fun and easy to keep bees. Spring and early summer are the best times to get started. Whether you get the bees from a neighbor, a bee breeder, or catch a wild swarm, you'll first need to get the equipment to keep them with. A hive and basic beekeeper's gear can cost as little as a few hundred dollars to as much as several thousand depending on how many extra gadgets and other accessories you'll want. But whether you're raising bees for profit or pleasure (or both!), the rewards of beekeeping make this investment worthwhile. Even if you live in an apartment or condo you can keep bees (assuming it doesn't break building code or lease agreement): there are specialized hives (or you can modify a standard one yourself) that can be kept inside so that the bees can only exit their hive through a tunnel to the outdoors, not into your home.

Every hive has several basic parts, and there are many more optional features that can be obtained or created. Bee hives can be painted or unpainted. If painted, it is better to not paint the inside, and does not have to be white. Painted wood does not breathe as well, and withstands the elements better than unpainted wood. This can be an advantage in dry, harsh environments, but can be a disadvantage in moister climates. We never paint our hives because it is unnecessary (even in our dry desert air) and the bees hate paint.

Hives can be bought pre-assembled or you can save money and assemble them yourself.



The modern bee hive is like a highly efficient multistoried factory with each "story" having a specific function. These "stories" work together to provide a home for bees and a honey factory for the beekeeper.

A) Hive Cover — telescoping cover "telescopes" over the sides of the top super to protect the hive. Galvanized covering.

B) Inner Cover — Creates a dead air space for insulation from heat and cold.

C) Shallow Supers — For "surplus" honey storage. Bees store their extra honey in these for the beekeeper to take. 6⅝", 5¾" supers, or even hive bodies may be used.

D) Queen Excluder — Keeps the queen bee in the brood chambers as she is too large to pass through the excluder.

E) Hive Bodies — "Brood Chambers" are the bee's living quarters. Queen lays eggs in these chambers and brood is raised. Honey is also stored for the bees' food.

F) Bottom Board — Forms the floor of the hive. Shown with wooden entrance reducer in place to keep mice and some cold out during winter.

G) Hive Stand — Supports the hive off the ground to keep hive bottom dry and insulate hive.

Successful beekeeping means easy manipulation of the frames of brood and honey to provide a "surplus" of honey beyond that needed by the bees to live on and rear their replacements. It is this "surplus" that the beekeeper removes and markets.

Components of the Hive

(illustration from Western Bee Supply, westernbee.com)

The basics:

Hive stand – this is the bottom of the hive, upon which sits the bottom board.

Bottom board – this is the "floor" of the hive. It can be solid or screened. Screens improve ventilation and help control mites, but can be a disadvantage in cold weather.

Hive body – this consists of two supers (though they are not called that when used here, they are the same equipment) with frames and foundation. This is the part of the hive where the queen lives and the brood is raised.

Queen Excluder – this is a screen that is designed to have large enough openings for the worker bees to pass through it but too small for the large-bodied queen to pass through it. This keeps the queen from leaving the hive body, so that she cannot lay eggs in the supers above.

Supers (also called "boxes") – these boxes are of the same construction as those of the hive body, but are called supers because they are the "extra" boxes that are placed on top for the bees to store honey in. These are filled with frames and foundation from which honey will be harvested.

The supers go above the queen excluder, so that the queen does not lay eggs where honey will later be harvested. Supers come in three depths. The smaller the depth, the less honey it will hold but the lighter it will be to lift off for harvesting. Smaller supers – whether used in hive bodies or for production – are easier for the bees to work, allowing easier temperature regulation, humidity control, disease and predator defense, etc. A shallow super (5 3/4" deep) weighs about 40 lbs when filled with honey, a medium super (6 5/8" deep) weighs about 60 lbs when filled, and a deep super (sometimes called a standard super, 9 5/8" deep) weighs about 80 lbs when filled.

Frames – The frames are holders for the foundation, and are designed to rest in the supers or hive body and be easily removed for maintenance and harvesting.

Foundation – This is the beeswax sheet from which the bees build their combs and in which they store their honey and raise their brood. Foundations come in many designs for many purposes. These include foundations with plastic support, wire support, or no support; and special shapes like circles for shaped comb honey. Foundation is not necessary, but does help the bees be more efficient with their hive's space and with their supplies of wax.

Entrance cleat – This is a small piece of wood that has various size holes in it (or several pieces, each with a different size hole) that goes in front of the bee's entrance. It allows the bees a larger or smaller doorway to their hive. Larger doorways are good for hot weather at the peak of bee activity, when many bees are trying to get in and out of the hive. However, large doorways are more difficult for the bees to defend. Small doorways are best in cold weather so that less heat escapes the hive, or when the bees need help defending their hive against invaders.

Feeders/waterers – there are many styles of feeders and waterers. They should be accessible to bees so that they don't have to fly far from their hive (or not leave it at all, especially if it's cold out), but don't drown in it. There are top feeders, which sit on top of the uppermost super, and are designed so that the bees can eat without leaving the hive, feeders that can be slid into the hive entrance, and feeders that go outside the hive. Feeders are easy to make, too.

Hive top – This is the "roof" of the hive. It can be plain wood, wood with metal (to protect against elements, but can get hot in the sun), or decorative.

The Accessories:

Bee escape board – this board has a whole with a screen in it, that is designed so that bees can only pass through it in one direction. It is most commonly used when preparing to harvest a super, but can be used at other times such as hiving.

Slatted rack – this goes board goes on the hive bottom board to increase air circulation and prevent cold drafts from chilling the front of the hive.

Pollen trap – use this if you want to collect pollen instead of honey.

Propolis trap – use this if you want to collect more propolis that would usually be available at harvest.

Frame spacers – these allow you to evenly space the frames at a wider distance than is typical, with the purpose of obtaining a greater honey harvest.

Mouse guard – this keeps mice from getting in your hive.

Bee House – this is a tool we invented at Coastalfields, and houses the hives against extremes of weather and wind. Bees love to make their homes in abandoned human structures, so we built one just for them and put nice hives inside. They love it. More about this later.

General Purpose Tools

Hive tool – Hive tools are essentially specialized combination crowbars and scrapers. They are used for many tasks, and especially for prying frames out of supers and hive bodies for inspection and harvest, and for scraping the frames for cleaning.

Smoker and smoker fuel – Smokers are used for many reasons whenever you need to work in the hive or catch a swarm. Bees will move away from smoke, and can be used to drive bees either out of a super when you need to take that super, or into a hive when retrieving a swarm. Smoke also masks the smell of the beekeeper, and can be used to trick the bees when handling them: bees recognize people by their smell, and can associate a person's regular smell with one sort of activity (such as a non-threatening activity) and the smoker smell with another sort of activity (such as "stealing" their honey). Thus, if you smoke the bees when they would otherwise become aggressive to defend their hive, they will be both distracted by the smoke and will not realize that you're the same person when you approach them otherwise.

Smoker fuel can be any number of materials, but should be something that will not flavor the honey and is safe for both bees and beekeeper to inhale. Most popular is cotton, but burlap can also be used. New products are now on the market that replace smoke and smokers with "liquid smoke" – not the stuff used for barbequing – which is supposed to work like smoke but is sprayed with a squirt bottle.

Bee brush – This is a soft brush that is used to brush bees off of frames, into hives, or wherever else they need moved, without hurting them.

Clothing:

Many beekeepers work without any safety clothing or gloves at all. If your bees are calm, you have an immunity to bee stings, or just prefer working with bees au natural, bee clothing may be of little to no use. Also, working without gloves will make it easier to feel a bee when you put your finger on it before you press it too hard, allowing you to release the pressure before the bee is hurt or stings you. This requires sensitive fingers and quick reflexes, but is preferred by many beekeepers. Whatever bee clothing you decide to wear, never wear wool, sheepskin leather or black when working with bees – they hate sheep, and the color black!

It is also a good precaution to wear a smile while you work. Bees can smell and are disturbed by the smells humans make when they fear, worry, hate, saddened or are otherwise disgruntled. Bee happy when working with your bees, or else you will be stung. Bees communicate through smell and touch primarily, visually and audibly secondarily.

Veils – these come in different sizes and styles. The smallest and most basic is one that will fit on a baseball cap and folds up small to keep in a pocket. Larger ones are wired to stand out away from your face.

Bee suits – these come in different styles and vary on the amount of a person's body that would be covered. They cover more than just a veil. We just use a bug baffler mosquito net shirt, which is excellent because it keeps off the bees AND the mosquitoes!

Gloves – while regular leather gloves often work fine for beekeeping, many specialized gloves are available. These usually extend up to the elbow. Make sure to tuck them into your shirt or you'll get a bee up your glove! (And wear long pants to tuck your socks into!)

Breeds of bees

Not all bees are honey bees: the bee family has a large variety of members including bumble bees, mason bees, carpenter bees, cuckoo bees, and leafcutter bees. Not all bees make honey, and some bees are even solitary. Some bees are don't even have stings!

All honeybees are of the species Apis mellifera. Within this species, there are many breeds, each with their own unique characteristics. Some beekeepers prefer one breed, others another, just as some dog owners prefer labs and others poodles. Which breed is right for you depends on what you are looking for!

While few bees are "true" breeds (most have become crossed with other breeds at some point), some beekeepers carefully control the genetics of their bees to keep their hives as true as possible. Some beekeepers also carefully breed their bees to make hybrids (crosses between breeds). Most beekeepers even prefer to use "naturally hybridized" bees – those that are from feral bees that cross-bred themselves in combinations unknown to the keeper. These bees, whether bred from one's own hives or caught in the wild, are sometimes more adapted to the local environment than more carefully bred bees. These bees are sometimes sold under the breed name that they most closely resemble. When buying bees, therefore, it is important to inquire thoroughly with the seller as to how true to type their bees actually are, and if possible examine them yourself.

Genetics and handling both work together to cause an individual hive to be more or less gentle, productive, and otherwise "good" when compared to other hives of the same and of different breeds. More than selecting a breed for its good qualities, it is a better idea when possible to select a hive for its own individual qualities. While it is possible to buy an established hive that you can inspect for temperament, it is more usual that the beekeeper does not meet their hive until the Queen establishes it in their apiary.

Breeding bees is tricky. You can segregate the females and males you wish to mate and hope that they do so, you can use elaborate equipment to artificially inseminate the Queen. Or, you can let nature take its course. Typically, beekeepers let nature take its course.

Many bees are typically purchased from breeders in "nucs" (a Queen and small escort), by the pound (with thousands of bees per pound, and usually the assurance that there is one Queen in there too), or in the purchase of a single Queen. Bees are also commonly (and carefully) collected as they swarm in the wild, or enticed with empty hives.

Italian: Sometimes called Golden Italian, these are the most popular honeybee. They are best known for their gentle temperament, excellent honey production, and low tendency to swarm. It is also considered one of the least disease resistant bees, especially for mites. They will raise brood regardless of conditions: this can be a benefit by having a quicker start to the season, but can also lead them to exhaust their stores and need supplemental feeding so they don't starve in the winter. They will also rob other hives of honey when pollen is not highly available.

Carniolan: Carniolan bees are very gentle, and they build up their populations very rapidly in the spring. Because of this, they are more likely to swarm if not given sufficient room for their rapidly growing populations. They build excellent combs but don't produce as much honey as Italians.

Yugo: This breed over winters well and is not prone to swarming. It is often selected for its disease resistance. This breed was registered with the USDA in the 1990s as an improvement on a

Yugoslavian Carniolan breed. Since it is a new breed, it is not highly studied nor highly available. Those that do sell it have often hybridized it with other breeds.

Caucasian: These bees take longer than Italians to build up their population in the spring. They build more propolis than Italians; they also have longer "tongues" (proboscis) so they can gather from flowers that other breeds cannot. They are considered to be more likely to rob other hives and also more likely to sting when handled when compared to many other breeds.

Russian: These bees are considered as gentle as Italians but more disease resistant. They only raise brood when conditions are favorable, which can delay their early pollen collection and thus lower the amount of honey produced; however they are also less likely to starve in the winter because they will keep the population at a sustainable level.

Cordovan: This is not actually a breed, but a genetic trait. It is a recessive gene that most often appears in Italians. It is desired by some because it affects the coloration of the bees, making the queen more easy to locate.

German Black: These bees went feral in America hundreds of years ago after they were introduced to this continent. They are ill-tempered and are not considered very suitable for honey production.

Beekeeping in urban areas

Beekeeping is a profitable enterprise in urban areas where demand is high, transportation costs are low and not much space is available for the keeping of livestock.

Before you buy a beehive, be sure to check with your local laws to see if you are allowed to keep bees in your home or yard. It is also sometimes advisable to check with your neighbors and let them know what you'll be doing. Many people are afraid of bees but will willingly support your efforts if you offer to teach them about the bees, explain bee behavior and safety, and offer them a bit of free honey once your harvest is in.

Once you have your hive equipment, you're ready for the bees themselves. There are many ways and places to obtain bees. Factors for each source to consider are cost, difficulty, and availability.

The cheapest way to get bees is by getting a wild swarm. In the late spring and early summer, bees that have outgrown their old home will raise new queens and send her off with many workers to start a new colony. This can be risky: you may have to wait a while to get one and requires some planning. The bees will also be of unknown breed, and most likely hybridized: this can be a benefit or a disadvantage, depending on what you are looking for.

There are two ways to get a wild swarm. You can catch a swarm as it rests during its travels, by physically scooping, shaking, and smoking the swarm into a portable empty hive. However, you may never know a swarm is available for this if you don't see it or you are not told of it in time by someone who does. Even if you do know of it, it may rest somewhere unsafe to reach. Swarms will rest on a branch or other object for as short as a few minutes to as long as (in very rare circumstances) a few days. To catch a swarm like this requires you have all equipment and yourself ready to go and hive it within minutes, or it might fly away! Try posting signs in local businesses, and tell everyone you know to spread the word to call you if they see a swarm in order to get a better chance at locating one. Some counties and cities also have a bee removal employee or contractor who might be willing to give you or sell you a swarm that they are called out to remove.

Another way to get a wild swarm is to set out an empty hive, preferably in a bee flyway. The local bees will investigate it, and when they are ready to swarm they will remember it and hopefully move into it. This is an easy way to get a swarm, but does require that the bees find your hive so they can move into it.

Another way to get bees is from another beekeeper. They are sold in several ways: as whole hives, as packages, and as nucs.

Whole hives are an easy way to start, but are very hard to find. Most beekeepers don't get rid of whole hives, and when they do it is important to find out why they are getting rid of their whole hive: is it sick? is it aggressive? is the keeper moving or getting out of beekeeping? An established hive will be more likely to yield honey for you in the first year than any other method; they are also available for more of the year than other sources. Whole hives cannot be shipped; ask around to find other beekeepers and ask if they or anyone they know would sell you a hive. Some areas have beekeeping clubs and these are good places to start asking.

Packages are a box full of worker bees with one (individually packaged) queen. They are typically sold in one, two or three pound packages, and can be mailed to you from across the country. They are easier to establish in a hive than bees shipped as nucs (soon to be described). Packaged workers are often taken from a different hive than the queen and her few helpers, and so they require a special (but simple) set up for the first few days while the workers accept the queen. Packages are typically only available in spring and early summer; some vendors limit their seasons even more. Some companies sell out even a year in advance, and some companies almost always have more to sell, so if you're ordering at the last moment you may need to call around.

Nucs (sort for nuclear) are small packages of workers with a queen. They are cheaper than regular packages, but their small size makes life harder for them while they establish in their new hive. To give nucs a good start requires a bit more attention than the other methods: to help the small nuc hive build up quickly, assisting with their temperature regulation and food and water availability can save their energy for helping the queen raise more brood. Like packages, nucs are typically only available in spring and early summer, and some companies sell out early.

Bees recognize their master and their enemy

Sindya Bhanoo of the New York Times (*If You Swat, Watch Out: Bees Remember Faces*, Feburary 1, 2009) reports that Martin Giurfa, a professor of neural biology at the University of Toulouse in France found that bees can recognize different faces of people, and the experiments of world-famous beekeeper Ormond Aebi confirms that bees can differentiate the smells of different people.

Castes of bees include Queens, Drones, Workers; workers divided into principle tasks, with some being used for the manufacture of wax, others for harvesting and honey making, others for security, and others for hygiene, etc.

There are three principle castes of bees: there are drones, which are the male bees whose life consists of mating the Queen, and then dying. There are workers, who undertake almost all the normal activities of the hive, and there is the Queen. Contrary to popular belief, she does not principally order the colony through chemical, audible, visual and tactile communication, her principle job is to lay eggs. The ordering of the colony is undertaken by the numerous workers whose jobs are to direct their fellow workers, who receive communication and information on the

status of the colony and its activities. Chief among these supervisors is the bee or bees who stand at the hive entrance to communicate and aid those bees leaving and arriving, and those bees who undertake security patrols about the hive. Also chief among these supervisors are the bees who oversee the care of the baby bees, and the production of honey. Some workers have as their only job to produce wax. The wax is harvested from these bees by their sisters who then use it in the normal hive activities of expansion, care for young bees and honey production.

Bee biology

Bees, like all insects, have three phases of growth before adulthood: they are laid as eggs, they hatch into larva and then become pupa. Some Queens lay more than 2,000 eggs per day. The Queens lay them into the hexagonal cells of the hive.

The eggs resemble grains of rice, and beekeepers who have just installed a new Queen or established a new hive anxiously will check after a week or so to see if any of the cells have eggs in them. If you do not see any, hold the cells up to the light and look for something that appears to be a tiny grain of rice. Each egg is attached by the Queen to the bottom of the cell. Within 3-4 days, the baby bee will curl into a C shape with its tail and head touching.

The baby bees are fed a special feed called royal jelly, a rich food secreted from the glands of young workers. The larvae are then fed pollen and honey by older bees, known as nurse bees. The larva moults its skin 4 times until, by the end of the 8th day, its cell home is capped by its nurses. Then the larva spins a cocoon of silk from a gland in its head and goes into the pupal stage lying quietly on its back with its head towards the cell opening. As a pupa, the bee moults 2 more times. Then, color can be seen in its eyes, and it grows out its abdomen, legs, wings and antennae. The last moult occurs on the 20th to 23rd day and the baby bee ends its metamorphosis and begins its "imago" stage when it chews threw the cell to emerge as a fully developed adult bee. The new adult then rests a few days before beginning her work – first feeding older larvae, and then other larvae, and then doing other work around the hive as a "house" worker. Towards the end of her life, she is given duties outside the hive, including harvesting and security. Most bees undertake a shift in wax production. If you see bees hanging together with feet locked, they are in a trance-like state as they excrete wax. Their sisters will harvest the wax and mold it into shape where it is needed. A very important job of house bees is maintaining temperature and humidity by fanning air and fanning drops of water, both can be easily controlled. Bees will rest about 1/3 to 1/2 of the day, but are always ready to fly into action where needed in an emergency (they are light sleepers). In larger hives, there are both day and night shifts, but bees are largely diurnal.

Queens and drones are raised in a similar manner, except they are fed royal jelly throughout their youth. Both Queens and drones have specialized cells for their metamorphosis.

A worker bee will typically live only 4-6 weeks during the season if they are a harvester. A Queen typically lives 2 to 5 years before being replaced by her daughters with a new Queen. If kept out of a hive and nursed in captivity, a Queen can live decades. She is typically killed by her daughters or the new Queen when no longer laying eggs at peak efficiency. When a hive prospers, they may produce many Queens. Some are sent off with a royal escort to found a new colony. Typically, some workers have already scouted out a good location (hopefully the bee trap you set out!) and these scouts will lead the new Queen and her escort to the new colony site. If the colony needs a new Queen, one or more Queens will battle the existing Queen to the death. Sometimes in these matches the Queen wins, usually her daughter wins.

Bees communicate very complex things to each other. In harvesting, they can communicate good flower areas in terms of distance, direction and height from the ground, explaining to their companions how to even avoid some obstacles in the way. They do this through dances on the outside of the hive, accompanied by songs and chemicals. Sometimes they use their antennae and legs to touch each other to express things. House bees communicate similarly.

When the security bees on guard detect a threat, sometimes even the house bees are called out for the defense of the hive. Sometimes, when there is much work to be done inside, the outside workers are rushed inside. The guard bees, those who patrol just outside the hive in the air and those who patrol on the entrance (inside and out) are responsible for conveying this information to the bees that are coming and going.

There are many books on bee language, and the intelligent farmer can learn the dances and songs of their bees to understand what is going on so that they can provide for the needs of their bees better. Bees are highly intelligent, and beyond providing shelter and occasionally food in the spring or water in the summer, there is little that a beekeeper needs to do for their animals.

Selling pollination services is not easy money: transportation and protection of bees against chemicals is hard work

Some beekeepers will plant food for their bees, but most accept payment from other farmers for putting their bees in the middle of orchards or cropfields to undertake the service of pollination. This does not seem like a bad deal to the beekeeper: their bees get food and get paid for it – on top of the honey that is produced! However, many farmers use insecticides and this kills bees. Also, some orchards are monocultures and the bees can get malnourished if only fed on one kind of flower. Plus, the hassle of moving hives from one location to another is remarkable. So, while it seems ideal at first, in selling the pollination services of their bees, the beekeeper earns every penny.

Watering bees

Bees can drink water from standard livestock waterers, ponds, and even moving water, but an ideal waterer for bees is a bird bath modified with an island in the middle. On this island, plant a few plants. The plants and island are ideally made with a flowerpot! The island and plants help the bees drink without drowning by providing a walkway to the water. Some beekeepers will fill the entire birdbath with gravel, mounding it in the middle to make the island and do not provide a plant. This also works well.

Position the waterer near to the bees so they do not have to travel far to get a drink! They need the water also to maintain hive temperatures. Keep the water clean for the bees!

Feeding bees

To jumpstart your hives in the spring, as soon as the bees begin to emerge, provide them some unfiltered raw honey, either from your own harvest last year or from someone else's harvest (if you sell premium honey, this may make sense: you may not want to use your valuable honey when there is a cheaper alternative). Bees prefer pollen, but the early sugar will help them get ready for when the flowers begin to bloom in earnest.

Some beekeepers will feed their bees with a boardman feeder, a device that provides honey directly into the hive entrance. However, this invites trouble from ants, bears, raccoons, mice and other creatures that would like a honey snack. Provide the honey near to the hive, but at a respectful distance (near to your water is good). We have used a teacup saucer to great effect: the honey is shallow and not many bees will drown, there is plenty of lip for them to land on. To make it better, we put bits of wood on top for them to land on.

Some beekeepers prefer feeding pollen to honey for its high protein content and nutrition, especially if the bees are going to be fed for a longer period of time. If using pollen, make sure that it is actually pollen and not a substitute, or if it is a substitute, that it is not toxic to bees. There are many bad products on the market.

Some beekeepers will feed the honey to the bees on a plate kept under an empty box under the roof of the hive: this keeps the honey out of sight (if not out of smell) of animals that would eat it, but within very reach of the bees. But, it is not as effective as an outdoor feeder: the bees need light to avoid getting caught in the sticky mess! A slightly better option is to fill a very shallow plate with some honey and slide it into the entrance of the hive. At night, remove it with a crooked wire to avoid opening up the hive. But, as bad as feeding bees inside their hive is, making them come out of the hive in the winter is worse, so consider slipping them a plate of food through their entrance or, if the entrance has been blocked up to a tiny hole for the winter (doing so helps retain heat in the hive), put the feeder on top.

Feed your smaller hives before winter. Let them store lots of it in their cells so that you don't have to feed them in the winter.

Your bees will quickly recognize the honey plate and your face, and will come out to greet you whenever they see you. They will bump into your face and crawl on you, not out of aggression, but out of joy and friendship!

Cleats, blocks and dealing with robber bees

Some bees do not harvest pollen, but only rob productive hives. Some bees turn "bad" and start robbing their neighbors. If your hives are being robbed, reduce the size of the hive's entrance with cleats and blocks, allowing only a small ½ inch to 1 inch opening for the bees to come and go: this makes it easier for the guards to defend the hive. In summer you don't want to reduce air flow: you want the hive to be cool. So, instead of blocking with wood, block with a screen or with some bundled grass.

It is a good idea too to reduce the size of the hive entrance in the winter so that less heat escapes. Some beekeepers have intermediate blocks as well.

If robbers persist, kill a few of them and rub the carcasses near the entrance, leaving the carcass if possible (the hive will likely dispose of the body, but maybe not). The robber's friends will get the idea and choose another hive to rob.

Getting your bees to like you: feed them, and then disguise your face and smell when you harvest and work in the hive

A good bonding activity with your bees is to hand-feed them. Put some honey on your hand and feed them daily. They'll remember your face and smell, and associate it with a tasty treat. They'll be much more forgiving when you work around them later.

Make sure to use smoke when you work in the hive and harvest, and if possible, obscure your face. You want your bees to think it was "the other guy" who robbed them.

Mortality and reproduction

It is not unreasonable to lose 20% of your hives every year to death, and it is reasonable to overcompensate that loss with new hives from swarms.

Establishing a colony

If you've bought bees or captured a swarm, you'll want to establish the colony. In the empty hive to which the colony will be transferred, first (if possible) insert the Queen. Then, insert as many of the bees as possible by gently shaking them into the box. Then, insert the frames and close the box with the covers. Sometimes it helps to only take out half the frames: this way you can more quickly close the box. If you received the bees in a box, leave the box near the entrance: the smell of the Queen might confuse some bees before they learn from their sisters that the Queen is actually in the hive.

Make sure to give the new colony only one box at first – if it is too big, the bees won't like it much. Besides, such a big area is hard for a small colony to maintain. If you have a very small wild or nuc, it is possible to nurse it into a magnificent colony. Ormond Aebi did, and produced a world's record of honey from such a small start. It'll require a great deal of nursing and supplemental food. However, as risky as this is, it sometimes is cheaper to buy nucs and nurse them into hives this way. No matter what size you begin with, it is a good idea to provide supplemental feeding to the new colony (of honey) until they are well established.

Do your bees like their new home? You will see the head guard bee come out of the hive entrance and begin singing with her wings to announce to everyone that they have a new home. This announcement will be soon followed by a dance as the bees mark their territory with their happiest smells. Soon, the new hive will begin functioning: the workers and Queen will work overtime to ensure that a new brood of bees is hatched before the founding bees die. You will see a lot of bees die in the first month or two: they will be working twice as hard as usual, and the strain is too much for them. Do not be discouraged if the dead bees pile up around the hive: normally, the bees leave their dead on the ground a fair distance from the hive in sheltered, hiding spots. But, in the crisis of a new colony founding, the bees will simply leave their dead outside the hive and clean up later. Save them the effort and avoid attracting animals that like to eat bees by sweeping the dead bees away from the hive. Chickens love dead bees, so keep your birds in mind!

If you see eggs, and then the eggs are capped into worker cells, you've got success. However, if you see only elaborate domes, you have a problem: your Queen is infertile and is laying only drones. If you see a mix, you have a problem: the colony is stressed and does not believe they will survive. Try putting some insulation on the hive and look to see what the problem is.

If your bees get sick, consult your veterinarian. They will typically prescribe an antibiotic, as bees are not susceptible to much, and what they are likely to be sickened by is usually cured by antibiotic. However, keep one eye open to see if they might be exposed to any insecticides in the neighborhood. Beekeepers must become very suspicious of their neighbors!

A standard frame can hold between 712 and 760 cells, and a Queen at the height of egg production will lay 1,000 to 1,500 eggs per day. This means that the Queen might fill up both sides of a frame in one day. With about 9 frames per box, and eggs taking 21-23 days to mature (leaving room for new eggs), at the peak of pollen production (or egg production) you want to ensure the Queen can have 3 boxes for laying eggs (under the Queen excluder – the frames above that the Queen cannot access if she wanted to). The brood will also require honey and pollen to mature, and you do not want to harvest that. As you add boxes to the brooding area, move several frames from the old box to the new box so that the bees are encouraged to use the new area.

Some beekeepers intentionally prevent the Queen from having enough space to lay eggs so that the colony is encouraged to produce new Queens. This works. These "breeder" hives help the beekeeper expand honey production quickly! When the bees begin to swarm, they are lifted into a new home – or a new home is kept waiting for them right next door to their mother hive for the Queen's escort's scouts to find.

However, it also works to give the Queen too much space to brood. Do not provide too much brooding space or the Queen will be encouraged to produce Drones and Queens. One large and one medium brood box are usually sufficient for most hives.

Some beekeepers will manipulate the frames to help the bees fill it up better: the bees prefer the inside of the box and will build a spherical area of activity. This is not to be done without extraordinary caution, as the bees know best what they need, and by interfering with their plans, you may be causing inefficiency for the bees and decreasing honey production.

One method of establishing a colony is to divide a very large one in half. Order a Queen, and she will come in a tiny box with perhaps one or two attendants. After physically dividing the hive in two, dividing both brood and honey boxes, insert the Queen in the hive without a Queen (you can always spot the Queen – she is very much larger than her workers!) without taking her out of her cage and allow everyone to meet and smell each other. Eventually, the new Queen will smell like the adoptive hive, and be adopted. It helps to spray the new Queen with honey water first – this disguises her smell and makes her an instant popularity with the workers. It helps to seal up the hive so no bees can come or go during this bonding (er, bondage?) process. Within a week or two or three, release the Queen from her cage and she'll likely be accepted. But do check up on her periodically to make sure that she has enough food and water.

We do not recommend re-Queening hives, the process of killing a Queen and replacing her. The bees are more than able to do this on their own if allowed, and will do it better and with better timing than you can.

Do not harvest honey from the newly established colony for the first year. They have not had the advantages of harvesting as much pollen as an undisturbed or established colony would and will likely need all that honey next spring.

Adding new boxes close to the brooding area encourages the bees to fill them. While this is inconvenient to the beekeeper who must lift the heaviest box from way on top every time to insert or access boxes in the middle, it encourages the bees to produce more honey. They understand they have honey in the top box, but want more in the middle near the brood! If they think there is much food in their hive, they will produce more brood and be able to harvest more pollen to make more honey. If they think there is not enough, they will not be so prosperous. Encourage your bees to

produce more not by starving and robbing them, but by allowing them to keep what they make. Harvesting the frames from 1 box 3 times is better than harvesting the frames from 2 boxes once.

Ormond Aebi, an expert beekeeper and two-time world record holder of the greatest honey production (he broke his own record), and author of the excellent book (in 2 volumes) *Mastering the Art of Beekeeping* suggests adding boxes in the following way above the Queen Excluder:

						1
					1	3
				1	3	4
			1	3	4	6
		1	3	4	6	2
	1	3	4	2	2	7
1	2	2	2	5	5	5
Queen Excluder	Queen Excluder	Queen Excluder	Queen Excluder	Queen Excluder	Queen Excluder	Queen Excluder
BROOD	BROOD	BROOD	BROOD	BROOD	BROOD	BROOD

Allowing your bees enough food for the winter (not harvesting all their honey) helps them produce even more the next year. Leave them more than 10 pounds more than you think they will use – it can always be withdrawn the next year.

Do not be concerned that the frames are not filled all the way. Bees need areas inside their hive not only for food storage and brood, but also for resting, dancing and other important bee activities. There will always be empty space, and these empty spaces are important.

Bees collect pollen in the daytime and convert it to honey at night. Give them extra space to store pollen during the day and by the next morning, they will have made it into honey.

Experimental hive structures

Ormond Aebi, the world's most accomplished beekeeper, in 1977 undertook a brave experiment to put the brood boxes at the top instead of at the bottom. Additional honey boxes were placed on top of the brood boxes, with two Queen excluders – one on top and one on bottom. However, the physical strain of moving the boxes was too great and he concluded that it made little improvement to the beekeeping process because of this extra effort required in lifting boxes.

But, to those who would continue his work, it is possible to install cranes around the hives to aid in the lifting and moving of the boxes. Strapping the boxes around the bottom, or the use of nets, allows a careful easy movement by ropes and pulleys that does not upset the bees much. We undertook tests, but are uncertain whether we would agree with Aebi that it is too much work and would advise anyone to similarly consider whether this improvement is worth their effort: at this time, we do not have enough data to suggest whether there is a significant improvement to honey production or bee health (though we have no reason to believe there is any significant harm or reduction, either). This is important work which should be continued.

Also, there are experimental orientations that stack the boxes horizontally instead of vertically. These are, as Aebi's central brooder was, claimed to be more efficient, but their novelty (like Aebi's invention) prevents long-term trends that might positively suggest they are or are not.

Always provide enough brooding area

If you have a good laying Queen, do not hesitate to give her more brooding area: you need bees to make honey.

And do not neglect to allow the bees to retain food for winter! While the Queen won't need all that brooding space and the hive does not need to keep extra space warm, consider replacing one or two brood boxes with unharvested honey boxes. Some keepers reduce the number of boxes to 1 or 2 for the winter so the bees can stay warmer, trusting the colony to expel the surplus bees and trusting the Queen to lay enough eggs for the following year. Depending on how harsh your winters are and how well the hives are sheltered, this may be unnecessary.

When clustering hives, Aebi cautions against clustering more than 200 in one location to achieve maximum honey production, and repeats Columella's sage advice that it is better to run a small farm well and admire large farms. Do not start with 200, but begin smaller and allow your bees to reproduce and swarm to help you expand.

Generally, do not provide more than one large brood box for your Queen for the first 3 years after the swarm has been hived. This helps the bees grow into their new home and establish a more logical and efficient use of space.

Pasture: prefer sanfoin, fruit orchard, alfalfa and clover

Do not be too concerned with poisonous plants. Though Buckeyes and other plants are poisonous to bees, they are generally smart enough to avoid them and prefer more wholesome foods.

Sanfoin is the most excellent pasture for bees, though tastes may dictate fruit orchard, alfalfa or clover. Every region has its preferences, but those four pastures (sanfoin, fruit orchard, alfalfa and clover) are most generally preferred.

Do try to provide a balanced diet to your bees – one kind of flower alone will lead to malnutrition.

Just as ranchers are allowed to graze cattle on national lands with permits, beekeepers are also allowed to. If you do not have adequate land nearby, consider applying for a permit from your local national forest or BLM area.

Caution on ladders

You will require ladders to reach the tallest boxes. Use caution! Or manufacture a crane, similar to the one used for moving sanfoin seed into wagons.

Clean dead hives and used boxes and frames

Before storing away used boxes and frames or dead hives, clean them out with some warm, soapy water and a little rubbing alcohol. Expose them to sunlight for a few days and store in a cool, dry place. Hygiene is important for bees, too!

Bees appreciate salt

Bees will appreciate a gift of salt – they normally will harvest this essential mineral themselves, but if you provide them salt, it will save them the effort of finding it themselves. They will take what they need and clean the rest off.

Drones serve many purposes so do not kill them! A lesson in letting things be

Besides the essential work of fertilizing the Queens, drones (male bees) are important sources of heat in a hive. They are big and they keep the hive warm, allowing their sister workers to do the important work that they cannot. Also, the observations of Aebi and other masters suggests that they may undertake social functions as well, organizing labor or encouraging their sisters. They are welcome in any hive – guards will never turn away a drone... until winter, when they are condemned to die because they are no longer needed (the Queen is no longer laying eggs, there are no new Queens to fertilize and wax working nearly stops).

It is a lesson to any beekeeper. Bees do everything for a reason and are very economical. Simply give them what they need – shelter, sometimes additional food, water, salt, a good location for the hive, defense against predators, maybe a good flower garden to eat from, etc. The bees will take care of the rest.

Work quickly to help bees maintain good hive temperatures

To work with wax, the hive must maintain hot temperatures and even on warm days, opening up a hive can set back production considerably. The bees like to keep their hive at about 95 degrees Fahrenheit, and even on a warm 80 degree day, or an even warmer 90 degree day, opening up the hive for a long time requires that the bees warm it back up again. They must spend their energy warming up the hive instead of gathering pollen and making honey. So, if you have to open up the hive, work quickly so that the entire hive does not cool down as you are working.

With this advice of working quickly comes the advice to try not to need to open the hive. Checking up on the bees is good husbandry, but doing it too often is bad husbandry. Try listening to the hive, watching the bees and undertaking other observations to get an idea of how well the hive is doing and only check up on the bees every month (or less frequently).

Do not open up the brooding boxes unless absolutely necessary: you might chill the eggs or young bees, and either kill them or delay their growth.

Always – ALWAYS – replace frames the way they came out as exactly as possible to avoid disorienting the bees and to allow them to be most efficient in the way they organize their hive. Bees do everything for a reason, and if they prefer something on the right side and it goes back in on the left, or something is moved from the middle to the front, or the front to the back, they are less efficient.

Replacing brood boxes

It is good to replace boxes and frames occasionally. Try to replace them every 5 years. This helps the bees be more efficient, keeps their hive hygienic and makes the honey taste better.

Certainly replace the frames as necessary: as the bees use their cells repeatedly, they become smaller and smaller until they become nearly useless. This you will have to check for annually.

If there is any chance that bees were killed due to insecticide, burn the equipment. Do not bury it, as the surviving bees might investigate and be killed.

Do not paint or oil the boxes or frames!

Bees hate paint and wood oils. Don't paint or oil boxes or frames. It also can be toxic to the honey, the bees or simply impair their ability to communicate with smell.

Sheltering and positioning hives

Hives can be placed directly on the ground, but it is best to elevate them somewhat so that it is more difficult for ground animals to get into the hives. A stand even 12 inches off the ground is usually sufficient to prevent ants from building nests underneath the hives, and makes it easier to defend the bees against ants if the ants do try to be bold and steal honey: a stand allows the farmer to put down chili powder or, in extreme cases, insecticide against ants. If the stand has a lip that would require rodents to walk upside down (which they cannot do), it also provides some protection against rodents. Make the stand of a shippery material (or cover it with one, such as metal sheeting or paint) and it is more effective. Keeping the hives elevated also helps bees access their hive entrance better: they do not have to navigate through tall grasses and plants.

It is a good idea in many places to shelter the hives themselves. While bees enjoy a windbreak to begin and end their flights, they also appreciate good fences to keep out the larger predators that might disturb their hives and especially enjoy human structures that protect them somewhat against birds, wind and other hazards. A shed with many open windows can shelter several hives and will keep them cooler in the summer and warmer in the winter, and can even be locked against human robbers as well.

It is helpful to the bees to hang a flag or paint a sign next to their hive. So they can easily recognize it from the other hives nearby. Being able to recognize both color and shape, each hive can be assigned its own "address," and this increase bee efficiency: they are no longer turning up at the wrong hive and being turned away as enemies. It is especially important when many hives are clustered together, whether in a building or out in the open.

Moving hives from one location to another may disorient the bees and should be avoided during their harvesting season. However, shifting hives less than 8 inches per day, and the use of flags or signs will improve the ability of the harvesters to find their home. Harvesters can travel miles and do not always return home at the end of the day. It is very disorientating to them to return to where their hive was only to find it is not there! If they can look about and see the flag or sign of home, though, they quickly adjust.

If your bees are outdoors and it snows, it is helpful to clear the snow from in front of their entrance so that they can continue to get air and maintain proper humidity. Position the hives in the open sun if they are outdoors so that they can dry out quickly.

If considering sheltering the hive, shelter it most from rain and snow: humidity is much more difficult for the bees to control than temperature! A canopy over the bees (sturdy enough to withstand snow!) helps magnificently. Make sure the canopy is tall enough to allow for very successful hives (which may require even 10 boxes above the Queen excluder).

Hives can also temporarily be wrapped in plastic or shielded with boards or cloth from the weather both as insulation and to resist precipitating moisture.

Also, hives may be tipped somewhat from the rear with a wedge so that there is a slight downward inclination towards the entrance. This helps excess moisture (condensed from their evaporating honey and weather) drain easier.

In rugged terrain, position hives at the south side of hills so that they may get the most and earliest sun: this will help the bees warm up for the day and get to work earlier.

Give a thought to yourself, too. Don't position the hives where it is hard to access them, and where you will not have to carry full boxes uphill or any equipment a very long distance. The day is long and hard enough. Don't add to your work.

Gentling bees

Bees can be made more tolerant of people in many ways. By putting their hive near a constantly moving object (such as a tree, or a flag, etc.), the bees become used to movement near the hive. The flag can double as an identification marker to help bees know which hive is theirs. If you put your hive in the middle of a field with no movement, they will become hypersensitive to the least bit of movement and will, in overcompensation to the lack of usual threat, overcompensate by being highly aggressive. If the bees have a problem with a particular animal or person, have that person or animal wear a piece of clothing for a few days to get their smell on it very well and hang that in front of the hive so that the bees will be harassed by it if it blows in the breeze. Eventually, the bees will work through their aggression and see that the smelly cloth does not hurt them, and forgive the person wearing it too.

Do not do much work with the bees in the morning: that is their busiest time – most nectar flows in the morning. Work with them on warm, clear days, in the afternoon. Of course, this is not always possible.

Do not drink any alcohol for many hours before working with the bees. Like wearing wool, the smallest smell of alcohol it is a sure way to make them very angry! Many perfumes also make them angry.

Move slowly and confidently, the bees will trust you better.

Begging for food

If bees are hungry, they will make a sound and movement to beg for food. Bees will feed hungry bees, but not sick, aged or injured bees.

The swarm dance

If bees are about to swarm, they will undertake a horseshoe dance above their hive entrance. You must then be ready either to house a new swarm, or delay the swarm by adding brood boxes and honey boxes.

Sell honey comb, not honey

It is really not a difficult choice to sell honey comb instead of honey. First, the beekeeper earns more per pound. Second, the beekeeper saves a fortune on labor and equipment. Third, comb stores longer and easier than pressed honey. One distinct advantage to comb is that, if you choose to harvest some of the brood box, you can sell the comb for a premium to some ethnic restaurants. But most people prefer their comb without baby bees.

The comb is easily cut from the frames with a hot knife. Package it in air-tight jars or boxes, and if possible refrigerate or keep cool. There is little risk of spoilage: the amount of sugar is toxic to most microorganisms, and there is little water in the raw honey. Be highly cautious of smells in the workroom: honey absorbs smells very well, and it can adversely affect the taste. This said, some beekeepers flavor their honey with pleasant scents of fruit or nuts this way.

Selling bee's wax and bee pollen is also profitable, but never so easy or as profitable as selling honey comb.

Marketing is also not usually a problem: everyone wants honey and will pay a royal ransom for it. As they should.

Suggested further reading:

- Beekeeping, an illustrated handbook by Diane G Stelley
- Mastering the Art of Beekeeping (in 2 volumes), by Ormond Aebi and Harry Aebi.

CHAPTER TWENTY-SEVEN: OF HUMAN NUTRITION

Feeding people is essential to a successful farm: farmers are people, and a farm without healthy farmers will not function well

The farmer must, besides feeding their animals, plants, fungi and microorganisms, must feed themselves and their families: farmers are people and a farm without healthy farmers will not function well.

Nutrient requirements of humans: tables and short explanation that overnutrition is as dangerous as undernutrition for some nutrients

The following tables were published by the Food and Nutrition Board of the National Academy of Science's Institute of Medicine. It is available online at http://www.iom.edu/Object.File/Master/21/372/0.pdf. The tables are organized to allow knowledge of both the minimum requirement and the maximum tolerated allowances in the following way:

The Nutrient ... Recommended Daily Intake ... Tolerable Daily Upper Level Intake

Overnutrition is as dangerous as undernutrition, and some nutrients are more dangerous than others to underprovide or overprovide. Some have little or no hazard if underprovided or overprovided.

Notes on the tables

- These are the values for a person whose total energetic intake reflects a moderately active lifestyle. As described in depth later, those who have more activity need more, and those who are less active need less.
- Research has not yet been conducted fully on all nutrients at all stages of life, and when there is no data available, the intake will be noted as "ND."
- Carbohydrates are represented only by the recommended daily intake: the diet should attempt to meet all nutrient needs while keeping as close to these values as possible (meet the Recommended Daily Intake for the various nutrients while eating—as closely as possible—the specified amount of carbohydrate).
- There is no intolerable daily upper level intake for fiber.
- Vitamin D may be created by the human body when the skin is exposed to sunlight (and not protected by UV-blocking sunscreens). The minimum value is designed to ensure that those who do not have regular exposure to sunlight do not get nutrient deficiencies. The maximum for Vitamin D represents the Vitamin D supplements and fortifications usually present in dairy products. However, many pollutants in the air from industrial activities and many

agrochemicals reduce or prevent the production of Vitamin D, as do many common medicines. Consult with a doctor to learn whether you have a deficiency, or provide supplementation just in case.

General guidelines if farmer does not want to count milligrams

Counting milligrams is difficult, here are some general guidelines to make human nutrition easier. These are based on the USDA "food pyramid."

At Every Meal You Should Eat Servings of: fruits, vegetables, whole grains and legumes

- Fruits
- Vegetables
- Whole Grains (includes Bread, Pasta, Crackers and other flatbread, Pita, Barley, Corn, Popcorn, Quinoa, Rice, Wheat, Lambsquarter, Rye, Buckwheat, etc.)
- Legumes and Beans

Only Daily Should You Should Eat Servings of: plant oil, nuts, seeds and dairy

- Plant Oil (ex. olive, corn, peanut, etc.)
- Nuts
- Seeds
- Dairy (including soy and other vegetable "dairy," such as soy "milk" and bean "cheese" [also known as "Tofu"])

Only Weekly Should You Eat Servings of: eggs and sweets

- Eggs
- Sweets

Specific serving suggestions: 6-11 whole grains, 5-9 fruits and vegetables, 2-3 dairy, if no dairy 2-3 additional raw leafy vegetables, 2-3 nuts and seeds and minimal eggs and sweets

This pattern of eating will generally prevent over consumption and under consumption of nutrients, but better protection is found by simultaneously ensuring that every day you have:

- At least 6 servings and no more than 11 servings of Whole Grains (includes Bread, Pasta, Crackers and other flatbread, Pita, Barley, Corn, Popcorn, Quinoa, Rice, Wheat, Lambsquarter, Rye, Buckwheat, etc.) and Legumes and Beans
- At least 5 servings and no more than 9 servings of Fruits and Vegetables
- At least 2 servings and no more than 3 servings of Dairy (including soy and other vegetable dairy).
- If no dairy is eaten, eat 2 to 3 additional servings of fresh raw leafy vegetables.
- At least 2 servings and no more than 3 servings of Nuts and Seeds
- Eggs, Sweets, Oil and added Salt can be omitted from the daily diet.

Adjustment for activity: if extremely active, increase values by 1/3, if sedentary, decrease by 1/3

If you are more than moderately active, increase these values by a third. If you are less than moderately active, decrease them by a third.

Keep data on food intake by food group per day to notice if guidelines are being followed, averaging over the course of a week; sample data table

Track intake of food by foodgroup by day to notice if these guidelines are being followed. We suggest taking a daily average over the course of a week. We have provided an example data sheet for convenience on the following page.

	Monday			Tuesday			Wednesday			Thursday			Friday			Saturday			Sunday		
	B	L	D	B	L	D	B	L	D	B	L	D	B	L	D	B	L	D	B	L	D
Every Meal																					
Fruits																					
Vegetables																					
Whole Grains																					
Beans																					
Once Per Day																					
Oil																					
Nuts																					
Seeds																					
Dairy																					
Weekly																					
Eggs																					
Sweets																					

★ 6 to 11 servings of Whole Grains , Legumes and Beans. 1 serving is 1 cup.
★ 5 to 9 servings of Fruits and Vegetables. 1 serving is 1/2 cup chopped or raw, unconcentrated juice.
★ 2 to 3 servings of Dairy (including tofu and other vegetable dairy). 1 serving is 1 cup.
★ If no Dairy is eaten, eat 2 to 3 additional servings of fresh raw leafy vegetables.
★ 2 to 3 servings of Nuts and Seeds. 1 serving is 1/4 cup.
★ 12-16 cups of of water
★ Enjoy carbohydrate-rich foods early in the day, protein-rich foods midday and nutrient-rich foods late in the day.
★ If you are more than moderately active, increase these values by a third. If you are less than moderately active, decrease them by a third. Exercise moderately to vigorously every day.
★ Hunger should be experienced daily.
★ Breakfast should not be avoided, neither should dinner. Have only two heavy meals and one lighter one.

Physical activity required for digestion; definitions of sedentary, lightly active, moderately active, very active and extremely active

You need to have some physical activity if you are to digest your food, and you need food to support your physical activity. The recommended intakes are for someone having moderate activity. It is a good idea to adjust your intake based on your activity: active people need more nutrients than sedentary people. First, figure out how active you are:

- Sedentary: you get little or no exercise (you work an office job). Decrease your intakes by about 1/3, and get more exercise: exercise does as much to improve your health as good food. Exercise aids digestion, aids organ efficiency, and strengthens tissues among other things.
- Lightly active: you get 20-30 minutes of continuous activity less than two times per week or less than a total of 60 minutes per week. This includes slow walking, yard work, gardening, leisurely cycling (5.5 mph), bowling, golfing with a cart, heavy housework, slow dancing, etc. Decrease your intakes by about 1/6 and increase your exercise.
- Moderately active: you get 30 minutes of continuous activity 3-5 times per week or more than a total of 90 minutes per week. This includes walking, jogging, leisurely cycling, calisthenics, golfing without the cart, slow swimming, leisurely canoeing or kayaking, weight lifting, aerobics, etc. Follow the recommended intakes and increase your exercise.
- Very active: you get 30-45 minutes of continuous vigorous activity more than 5 times per week or more than a total of 150 minutes per week. This includes skiing, rowing, canoeing, kayaking, fast dancing, jogging (5 mph), cycling (12 mph), basketball, hiking, lap swimming, running (10 minute mile), vigorous basketball or skipping rope. Increase your intakes by about 1/6 and increase your exercise. It is difficult to get too much exercise, and you are never too old to maintain a vigorous regimen.
- Extremely active: you get 45 minutes of continuous vigorous activity 5-7 times a week or more than a total of 300 minutes per week. Activities include competitive sports training for triathlon, a 10k race, singles tennis, competitive handball, racquetball or squash. Increase your intakes by about 1/3 and continue to become even more active!

Finding time to exercise is less difficult than you'd think. Even if you work three sedentary jobs, you can still be extremely active. It is simply a matter of placing priority on your health. Would you prefer to spend an hour watching television, or biking? Would you prefer to spend the afternoon sitting on your porch drinking alcohol and eating junk food or hiking in the mountains eating nuts, seeds and fruit? Take stairs instead of elevators or escalators (stairs don't maim or trap you nearly so often, anyway), and take them at a jog. Park further away from work or the store—or better, bike or walk to work or the store!

Taking care of yourself is the first step towards taking care of your world. Exercise with good diet does more to strengthen you than exercise or good diet alone.

If you need ideas on how to increase your exercise, you can contact your doctor, a friend or neighbor who is highly active, your local sporting goods store, your parks and recreation department, or just get up and go for a walk nearby or far away: you never know what adventure you'll find and the joy of freely exploring your world is enough to make anyone run and dance for happiness.

TABLES OF NUTRITIONAL REQUIREMENTS FOR HUMANS

These values present the minimum values to avoid injury and the maximum values to avoid injury, but do not necessarily present those values which are healthful, and do not present values adjusted for digestability.

In example, though an adult male human needs between 90 and 2,000 mg of Vitamin C, an example adult male might need consume 4,000 mg Vitamin C to absorb 1,000 mg. Some foods are more digestable than others, and some humans digest better than others: the human species is a young one, and there is yet a great deal of variation among its individual members.

On these tables, values are presented thus:
Nutrient ... Minimum ... Maximum

Infants 0-6 Months

Biotin ... 5 µg ... ND
Calcium ... 210 mg ... ND
Carbohydrates ... 60 g
Chloride ... 0.18 g ... ND
Choline ... 125 mg ,,, ND
Chromium ... 0.2 µg ... ND
Copper ... 200 µg ... ND
Fiber ... ND
Fluoride ... 0.01 mg ... 0.7 mg
Folate ... 65 µg ... ND
Iodine ... 110 µg ... ND
Iron ... 0.27 mg ... 40 mg
Magnesium ... 30 mg ... ND
Manganese ... 0.003 mg ... ND
Molybdenum ... 2 µg ... ND
Niacin ... 2mg ... ND
Pantothenic Acid ... 1.7 mg ... ND
Phosphorus ... 100 mg ... ND
Potassium ... 0.4 g ... ND
Protein ... 9.1 g
Riboflavin ... 0.3 mg ... ND
Selenium ... 15 µg ... 45 µg
Sodium ... 0.12 g ... ND
Thiamin ... 0.2 mg ... ND
Vitamin A ... 400 µg ... 600 µg
Vitamin B_6 ... 0.1 mg ... ND
Vitamin B_{12} ... 0.4 µg ... ND
Vitamin C ... 40 mg ... ND
Vitamin D ... 5 µg ... 25 µg
Vitamin E ... 4 µg ... ND
Vitamin K ... 2 µg ... ND
Zinc ... 2 mg ... 4 mg

Infants 7-12 Months

Biotin ... 6 µg ... ND
Calcium ... 270 mg ... ND
Carbohydrates ... 95 g
Chloride ... 0.57 g ... ND
Choline ... 150 mg ... ND
Chromium ... 5.5 µg ... ND
Copper ... 220 µg ... ND
Fiber ... ND
Fluoride ... 0.5 mg ... 0.9 mg
Folate ... 80 µg ... ND
Iodine ... 130 µg ... ND
Iron ... 11 mg ... 40 mg
Magnesium ... 75 mg ... ND
Manganese ... 0.6 mg ... ND
Molybdenum ... 3 µg ... ND
Niacin ... 4 mg ... ND
Pantothenic Acid ... 1.8 mg ... ND
Phosphorus ... 275 mg ... ND
Potassium ... 0.7 g ... ND
Protein ... 11 g
Riboflavin ... 0.4 mg ... ND
Selenium ... 20 µg ... 60 µg
Sodium ... 0.37 g ... ND
Thiamin ... 0.3 mg ... ND
Vitamin A ... 500 µg ... 600 µg
Vitamin B_6 ... 0.5 mg ... ND
Vitamin B_{12} ... 0.4 µg ... ND
Vitamin C ... 50 mg ... ND
Vitamin D ... 5 µg ... 25 µg
Vitamin E ... 5 µg ... ND
Vitamin K ... 2.5 µg ... ND
Zinc ... 3 mg ... 5 mg

Children 1-3 Years

Biotin ... 8 µg ... ND
Calcium ... 500 mg ... 2500 mg
Carbohydrates ... 130 g
Chloride ... 1.5 g ... 2.3 g
Choline ... 200 mg ... 1000 mg
Chromium ... 11 µg ... ND
Copper ... 340 µg ... 1000 µg
Fiber ... 19 g
Fluoride ... 0.7 mg ... 1.3 mg
Folate ... 150 µg ... 300 µg
Iodine ... 90 µg ... 200 µg
Iron ... 7 mg ... 40 mg
Magnesium ... 80 mg ... ND
Manganese ... 1.2 mg ... 2 mg
Molybdenum ... 17 µg ... 300 µg
Niacin ... 6 mg ... 10 mg
Pantothenic Acid ... 2 mg ... ND
Phosphorus ... 460 mg ... 3000 mg
Potassium ... 3 g ... ND
Protein ... 11g ... 13 g
Riboflavin ... 0.5 mg ... ND
Selenium ... 20 µg ... 90 µg
Sodium ... 1 g ... 1.5 g
Thiamin ... 0.5 mg ... ND
Vitamin A ... 300 µg ... 600 µg
Vitamin B_6 ... 0.5 mg ... 30 mg
Vitamin B_{12} ... 0.9 µg ... ND
Vitamin C ... 15 mg ... 400 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 6 µg ... 200 µg
Vitamin K ... 30 µg ... ND
Zinc ... 3 mg ... 7 mg

Children 4-8 Years

Biotin ... 12 µg ... ND
Calcium ... 800 mg ,,, 2500 mg
Carbohydrates ... 130 g
Chloride ... 1.9 g ... 2.9 g
Choline ... 250 mg ... 1000 mg
Chromium ... 15 µg ... ND
Copper ... 440 µg ... 3000 µg
Fiber ... 25 g
Fluoride ... 1 mg ... 2.2 mg
Folate ... 200 µg ... 400 µg
Iodine ... 90 µg ... 300 µg
Iron ... 10 mg ... 40 mg
Magnesium ... 130 mg ... ND
Manganese ... 1.5 mg ,,, 3 mg
Molybdenum ... 22 µg ... 600 µg
Niacin ... 8 mg ... 15 mg
Pantothenic Acid ... 3 mg ... ND
Phosphorus ... 500 mg ... 3000 mg
Potassium ... 3.8 g ... ND
Protein ... 15g ... 19 g
Riboflavin ... 0.6 mg ... ND
Selenium ... 30 µg ... 150 µg
Sodium ... 1.2 g ... 1.9 g
Thiamin ... 0.6 mg ... ND
Vitamin A ... 400 µg ... 900 µg
Vitamin B_6 ... 0.6 mg ... 40 mg
Vitamin B_{12} ... 1.2 µg ... ND
Vitamin C ... 25 mg ... 650 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 7 µg ... 300 µg
Vitamin K ... 55 µg ... ND
Zinc ... 5 mg ... 12 mg

Males 9-13 Years

Biotin ... 20 µg ... ND
Calcium ... 1300 mg ... 2500 mg
Carbohydrates ... 130 g
Chloride ... 2.3 g ... 3.4 g
Choline ... 375 mg ... 2000 mg
Chromium ... 25 µg ... ND
Copper ... 700 µg ... 5000 µg
Fiber ... 31 g
Fluoride ... 2 mg ... 10 mg
Folate ... 300 µg ... 600 µg
Iodine ... 120 µg ... 600 µg
Iron ... 8 mg ... 40 mg
Magnesium ... 240 mg ... ND
Manganese ... 1.9 mg ,,, 6 mg
Molybdenum ... 34 µg ...1100 µg
Niacin ... 12 mg ... 20 mg
Pantothenic Acid ... 4 mg ... ND
Phosphorus ... 1,250 mg ... 4000 mg
Potassium ... 4.5 g ... ND
Protein ... 27g ... 34 g
Riboflavin ... 0.9 mg ... ND
Selenium ... 40 µg ... 280 µg
Sodium ... 1.5 g ... 2.2 g
Thiamin ... 0.9 mg ... ND
Vitamin A ... 600 µg ... 1700 µg
Vitamin B_6 ... 1 mg ... 60 mg
Vitamin B_{12} ... 1.8 µg ... ND
Vitamin C ... 45 mg ... 1200 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 11 µg ... 600 µg
Vitamin K ... 60 µg ... ND
Zinc ... 8 mg ... 23 mg

Females 9-13 Years

Biotin ... 20 µg ...ND
Calcium ... 1300 mg ... 2500 mg
Carbohydrates ... 130 g
Chloride ... 2.3 g ... 3.4 g
Choline ... 375 mg ... 2000 mg
Chromium ... 21 µg ... ND
Copper ... 700 µg ... 5000 µg
Fiber ... 26 g
Fluoride ... 2 mg ... 10 mg
Folate ... 300 µg ... 600 µg
Iodine ... 120 µg ... 600 µg
Iron ... 8 mg ... 40 mg
Magnesium ... 240 mg ... ND
Manganese ... 1.6 mg ... 6 mg
Molybdenum ... 34 µg ... 1100 µg
Niacin ... 12 mg ... 20 mg
Pantothenic Acid ... 4 mg ... ND
Phosphorus ... 1,250 mg ... 4000 mg
Potassium ... 4.5 g ... ND
Protein ... 28g ... 34 g
Riboflavin ... 0.9 mg ... ND
Selenium ... 40 µg ... 280 µg
Sodium ... 1.5 g ... 2.2 g
Thiamin ... 0.9 mg ... ND
Vitamin A ... 600 µg ... 1700 µg
Vitamin B_6 ... 1 mg ... 60 mg
Vitamin B_{12} ... 1.8 µg ... ND
Vitamin C ... 65 mg ... 1200 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 11 µg ... 600 µg
Vitamin K ... 60 µg ... ND
Zinc ... 8 mg ... 23 mg

Males 14-18 Years

Biotin ... 25 µg ... ND
Calcium ... 1300 mg ... 2500 mg
Carbohydrates ... 130 g
Chloride ... 2.3 g ... 3.6 g
Choline ... 550 mg ... 3000 mg
Chromium ... 35 µg ... ND
Copper ... 890 µg ... 8000 µg
Fiber ... 38 g
Fluoride ... 3 mg ... 10 mg
Folate ... 400 µg ... 800 µg
Iodine ... 150 µg ... 900 µg
Iron ... 11 mg ... 45 mg
Magnesium ... 410 mg ... ND
Manganese ... 2.2 mg ... 9 mg
Molybdenum ... 43 µg ... 1700 µg
Niacin ... 16 mg ,,, 30 mg
Pantothenic Acid ... 5 mg ... ND
Phosphorus ... 1,250 mg ... 4000 mg
Potassium ... 4.7 g ... ND
Protein ... 44g ... 52 g
Riboflavin ... 1.3 mg ... ND
Selenium ... 55 µg ... 400 µg
Sodium ... 1.5 g ... 2.3 g
Thiamin ... 1.2 mg ... ND
Vitamin A ... 900 µg ... 2800 µg
Vitamin B_6 ... 1.3 mg ... 80 mg
Vitamin B_{12} ... 2.4 µg ... ND
Vitamin C ... 75 mg ... 1800 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 15 µg ... 800 µg
Vitamin K ... 75 µg ... ND
Zinc ... 11 mg ... 34 mg

Females 14-18 Years

Biotin ... 25 µg ... ND
Calcium ... 1300 mg ... 2500 mg
Carbohydrates ... 130 g
Chloride ... 2.3 g ... 3.6 g
Choline ... 400 mg 3000 mg
Chromium ... 24 µg ... ND
Copper ... 890 µg ... 8000 µg
Fiber ... 26 g
Fluoride ... 3 mg ... 10 mg
Folate ... 400 µg ... 800 µg
Iodine ... 150 µg ... 900 µg
Iron ... 15 mg ... 45 mg
Magnesium ... 360 mg ... ND
Manganese ... 1.6 mg ... 9 mg
Molybdenum ... 43 µg ... 1700 µg
Niacin ... 14 mg ... 30 mg
Pantothenic Acid ... 5 mg ... ND
Phosphorus ... 1,250 mg ... 4000 mg
Potassium ... 4.7 g ... ND
Protein ... 38 ... 46 g
Riboflavin ... 1 mg ... ND
Selenium ... 55 µg ... 400 µg
Sodium ... 1.5 g ... 2.3 g
Thiamin ... 1 mg ... ND
Vitamin A ... 700 µg ... 2800 µg
Vitamin B_6 ... 1.2 mg ... 80 mg
Vitamin B_{12} ... 2.4 µg ... ND
Vitamin C ... 65 mg ... 1800 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 15 µg ... 800 µg
Vitamin K ... 75 µg ... ND
Zinc ... 9 mg ... 34 mg

Males 19 Years and Up

Biotin ... 30 µg ... ND
Calcium ... 1000-1200 mg ... 2500 mg
Carbohydrates ... 130 g
Chloride ... 1.8-2.3 g ... 3.6 g
Choline ... 550 mg ... 3500 mg
Chromium ... 30-35 µg ... ND
Copper ... 900 µg ... 10000 µg
Fiber ... 30-38 g
Fluoride ... 4 mg ... 10 mg
Folate ... 400 µg ...1000 µg
Iodine ... 150 µg ... 1100 µg
Iron ... 8 mg ... 45 mg
Magnesium ... 400-420 mg ... ND
Manganese ... 2.3 mg ... 11 mg
Molybdenum ... 45 µg ... 2000 µg
Niacin ... 16 mg ... 35 mg
Pantothenic Acid ... 5 mg ... ND
Phosphorus ... 700 mg ... 4000mg
Potassium ... 4.7 g ... ND
Protein ... 46 ... 56 g
Riboflavin ... 1.3 mg ... ND
Selenium ... 55 µg ... 400 µg
Sodium ... 1.2-1.5 g ... 2.3 g
Thiamin ... 1.2 mg ... ND
Vitamin A ... 900 µg ... 3000 µg
Vitamin B_6 ... 1.3-1.7 mg ... 100 mg
Vitamin B_{12} ... 2.4 µg ... ND
Vitamin C ... 90 mg ... 2000 mg
Vitamin D ... 5-15 µg ... 50 µg
Vitamin E ... 15 µg ... 1000 µg
Vitamin K ... 120 µg ... ND
Zinc ... 11 mg ... 40 mg

Females 19 Years and Up

Biotin ... 30 µg ... ND
Calcium ... 1,000-1,200 mg ... 2500 mg
Carbohydrates ... 130 g
Chloride ... 1.8-2.3 g ... 3.6 g
Choline ... 425 mg ... 3500 mg
Chromium ... 20-25 µg ... ND
Copper ... 900 µg ... 10000 µg
Fiber ... 21-25 g
Fluoride ... 3 mg ... 10 mg
Folate ... 400 µg ... 1000 µg
Iodine ... 150 µg ... 1100 µg
Iron ... 8-18 mg ... 45 mg
Magnesium ... 310-320 mg ... ND
Manganese ... 1.8 mg ... 11 mg
Molybdenum ... 45 µg ... 2000 µg
Niacin ... 14 mg ... 35 mg
Pantothenic Acid ... 5 mg ... ND
Phosphorus ... 700 mg ... 4000 mg
Potassium ... 4.7 g ... ND
Protein ... 38g ... 46 g
Riboflavin ... 1.1 mg ... ND
Selenium ... 55 µg ... 400 µg
Sodium ... 1.2-1.5 g ... 2.3 g
Thiamin ... 1.1 mg ... ND
Vitamin A ... 700 µg ... 3000 µg
Vitamin B_6 ... 1.3-1.5 mg ... 100 mg
Vitamin B_{12} ... 2.4 µg ... ND
Vitamin C ... 75 mg ... 2000 mg
Vitamin D ... 5-15 µg ... 50 µg
Vitamin E ... 15 µg ... 1000 µg
Vitamin K ... 90 µg ... ND
Zinc ... 8 mg ... 40 mg

Pregnant (Females Only)

Biotin ... 30 µg ... ND
Calcium ... 1,000-1,300 mg ... 2500 mg
Carbohydrates ... 175 g
Chloride ... 2.3 g ... 3.6 g
Choline ... 450 mg ... 3500 mg
Chromium ... 29-30 µg ... ND
Copper ... 1000 µg ... 10000 µg
Fiber ... 28 g
Fluoride ... 3 mg ... 10 mg
Folate ... 600-1000 µg ... 1000 µg
Iodine ... 220 µg ... 1100 µg
Iron ... 27 mg ... 45 mg
Magnesium ... 350-400 mg ... ND
Manganese ... 2 mg ... 11 mg
Molybdenum ... 50 µg ... 2000 µg
Niacin ... 18 mg ... 35 mg
Pantothenic Acid ... 6 mg ... ND
Phosphorus ... 700-1,250mg ... 3500 mg
Potassium ... 4.7 g ... ND
Protein ... 50 g ... 71 g
Riboflavin ... 1.4 mg ... ND
Selenium ... 60 µg ... 400 µg
Sodium ... 1.5 g ... 2.3 g
Thiamin ... 1.4 mg ... ND
Vitamin A ... 750-770 µg ... 3000 µg
Vitamin B_6 ... 1.9 mg ... 100 mg
Vitamin B_{12} ... 2.6 µg ... ND
Vitamin C ... 80-85 mg ... 2000 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 15 µg ... 1000 µg
Vitamin K ... 75-90 µg ... ND
Zinc ... 11-12 mg ... 40 mg

Lactating (Females Only)

Biotin ... 35 µg ... ND
Calcium ... 1,000-1,300 mg ... 2500 mg
Carbohydrates ... 210 g
Chloride ... 2.3 g ... 3.6 g
Choline ... 550 mg ... 3500 mg
Chromium ... 44-45 µg ... ND
Copper ... 1300 µg ... 10000 µg
Fiber ... 29 g
Fluoride ... 3 mg ... 10 mg
Folate ... 500 µg ... 1000 µg
Iodine ... 290 µg ... 1100 µg
Iron ... 9-10 mg ... 45 mg
Magnesium ... 310-360 mg ... ND
Manganese ... 2.6 mg ... 11 mg
Molybdenum ... 50 µg ... 2000 µg
Niacin ... 17 mg ... 35 mg
Pantothenic Acid ... 7 mg ... ND
Phosphorus ... 700-1,250mg ... 4000 mg
Potassium ... 5.1 g ... ND
Protein ... 50 g ... 71 g
Riboflavin ... 1.6 mg ... ND
Selenium ... 70 µg ... 400 µg
Sodium ... 1.5 g ... 2.3 g
Thiamin ... 1.4 mg ... ND
Vitamin A ... 1200-1300 µg ... 3000 µg
Vitamin B_6 ... 2 mg ... 100mg
Vitamin B_{12} ... 2.8 µg ... ND
Vitamin C ... 115-120 mg ... 2000 mg
Vitamin D ... 5 µg ... 50 µg
Vitamin E ... 19 µg ... 1000 µg
Vitamin K ... 75-90 µg ... ND
Zinc ... 12-13 mg ... 40 mg

Many foods void of nutrition due to farming practices

With the poor farming practices of many conventional farmers, soil nutrients are consumed by plants and deposited in edible portions, harvested and removed from the field. Inadequate tillage and abundant chemicals prevent nutrients from being redeposited in the field. The subsequent crop is less nutritious than the previous, and eventually produce has little nutrition.

This phenomenon of agricultural-based malnutrition was described by the physician Dr. Mark Hyman, who has written many books on his miraculous curing of disease through supplementary nutrition (one of his more recent titles is *The Ultramind Solution*, 2008): he discovered much disease today is caused by people not getting enough nutrition, even when consuming quantities of fruits and vegetables. Dr. Mark Hyman suggests that, in addition to an antitoxic diet, food be eaten fresh from the field, raw (if possible) and in wild / natural soil (as is developed by Tullian methods). Short of that, consumers should supplement their diet with essential fatty acids, vitamins and minerals.

Many foods are highly toxic: farms should produce their own food for their human members

Should a farm produce its own food for its human members?

Besides being void of nutrients, many foods are highly toxic from the poisonous herbicides, pesticides and fertilizers many other farmers apply to the field.

Even while the question of what residual chemicals are actually within the foods consumed by the public is debated, there is a strong argument that there are chemical residues on foods but that they are simply not harmful. Even while it is debated whether those residues are harmful, there is a strong argument that there is no safe minimum quantity of those chemicals because they are so easily stored in the body until they gain a toxic threshold. Even while it is debated whether chemicals can reach a toxic threshold in the body, those who would desire their food to be free of such chemicals in the first place are derided as being fanatical or illogical.

Yet it remains a basic right – whether there are any chemical residues, whether those residues are harmful in any minute quantity – to have the choice of chemical-free food. And, at the same time, it is an impossibility.

The diffusion of chemicals from one field to another occurs easily. All chemicals have the potential to leach, or wash out, from the soil. When they leach, they enter into the groundwater, well water, or other water systems such as rivers. Chemicals have different rates of leaching, some are better at leaching than others. Besides leaching, many chemicals are applied through vapors or dust that travels by the wind.

Drift refers to the unplanned and uncontrollable movement of chemicals away from the application area through the air when applied as a spray. Most chemicals are applied as sprays because it is easily mechanized and easy to administer. This may be done by spraying close to the ground or from an airplane. When the spray is applied, it will be carried by the air currents to areas other than the intended area. It then settles on other plants, in the water, or around people.

Drift is usually impossible to see, since the particles carried through the air are too small for the human eye to discern. Chemicals can drift more than 50 miles away (Pesticide Action Network North America (PANNA). *Secondhand Pesticides: Airborne Pesticide Drift*)! While the chemical may become too diffuse to have much effect, this is not necessarily the case: some toxins are very potent

even in small quantities. Drift can, and does, have important and dangerous effects on the environment.

What does not drift or leach can remain in the soil a very long time, providing small quantities of poison to future crops – sometimes for decades to come.

And then there are the chemicals which are not applied by farmers at all, but are fallout from industrial practices in nearby (or faraway) cities, nuclear industry practices, nuclear bomb tests and the mining of petroleum and other minerals. Some mining practices pollute groundwater supplies, which are then applied in agricultural and culinary uses.

This combination of factors results in an inability for a person to obtain food without chemicals. Rachel Carson in *Silent Spring* discusses this in greater depth and the subject has already been explored in this book, but it suffices to say that it is easy to obtain critical quantities of poison over the course of a lifetime (or even a few years – or less) by eating food: slowly, surely, the small quantities of poison build up in the body until they become problematic: "We know that even single exposures to these chemicals, if the amount is large enough, can precipitate acute poisoning. But this is not the major problem. The sudden illness or death of farmers, spraymen, pilots, and others exposed to appreciable quantities of pesticides are tragic and should not occur. For the population as a whole, we must be more concerned with the delayed effects of absorbing small amounts of the pesticides that invisibly contaminate our world." The dangerous bioaccumulation that Carson describes killing animals that eat poisoned plants and that eat animals that ate poisoned plants applies to people, too. On this, Dr. Mark Hyman agrees.

While the USDA Organic Act was designed, to some extent, to secure this right of consumers to have chemical free foods, farmers are allowed to use so many synthetic and organic chemicals – some of which are highly toxic – that they need not actually alter their farming practices greatly to gain or retain "Organic" certification (*Organic Lies*, Mary Choate 2006). Yet, even if a farm were to not use any chemicals, the overwhelming presence of them in the environment would still present a danger to the consumer.

One result from gradual chemical poisoning: cancer. Disturbing evidence of a cover-up of increased cancer rates

Cancer is a likely result of this continual, low-dose chemical poisoning. In 1900, malignant growths (including lymphatic and blood-forming tissues) accounted for 4% of the deaths (Carson). The Office of Vital Statistics for July 1959 reports that malignant growths (including lymphatic and blood-forming tissues) accounted for 15% of the deaths in 1958 (Carson). The United States Centers for Disease Control reports that, averaged between 2001 and 2005 there was a death rate of 189.8 per 100,000 people (http://apps.nccd.cdc.gov/DCPC_INCA/ DCPC_INCA.aspx), but as cancer remains the leading and second-leading cause of death (CDC National Vital Statistics Reports, http://www.cdc.gov/NCHS/ data/nvsr/nvsr57/nvsr57_14.pdf), this significant decline reflects more on the overall declining death rate and the wider availability and diversity of treatment options for cancer.

Yet, more disturbingly, this decline may also be due to misreporting of data. the Journal of the National Cancer Institute in their article *Are deaths within 1 month of cancer-directed surgery attributed to cancer?* (Janice Hopkins Tanne. vol. 94 pg. 1066: http://www.vaoutcomes.org/papers/Cancer_Deaths.pdf) describes how many of those who die while undergoing treatment for cancer are

not reported to have died from Cancer: "Among patients with only one cancer, there were 4135 deaths within 1 month of diagnosis and cancer-directed surgery for the 19 solid tumors. Of these deaths, 1707 (41%) were attributed to something other than the coded cancer. There was considerable variation in the pattern of attribution among the 19 tumors (Table 1). The proportion not attributed to the coded cancer ranged from 13% for cervical cancer to 81% for laryngeal cancer. Selected intermediate values include 25% for esophageal cancer, 34% for lung cancer, 42% for colorectal cancer, 59% for breast cancer, and 75% for prostate cancer."

Doctors Michael J Thun, and Phyllis A Wingo, in their article *Cancer Epidemiology* report that "the magnitude of the human and economic costs of cancer in the United States is enormous. At current rates, invasive cancer will be diagnosed in approximately 1 of every 2 American men and 1 in 3 women in their lifetimes. Cancer afflicts 2 out of every 3 families" (http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=cmed&part=A5081).

The CDC reports that there was between 2001 and 2005 an average national incidence rate of 473.4 per 100,000 people. This 0.4734% rate, with an average life expectancy hovering at about 70 years for most Americans, lends credence to Thun and Wingo's suggestion that 42% of Americans will be diagnosed with cancer.

Other effects of gradual chemical poisoning

Other effects of gradual chemical poisoning are difficult to measure: the subtle ways in which the poisons disrupt cellular and organ function in a body can result in any number of diseases. Predisposition to disease becomes the disease itself, and while it is possible that a person may have become sick with a disease anyway, proving that gradual chemical poisoning is responsible is nearly impossible: a drunkard may fall over regardless of what happens around them, and proving that they were pushed over is difficult. But this is no reason to tip the drunk: there is no need for people to expose themselves to the danger and risk falling over the brink.

Dr. Hyman reports that the average American eats many pounds of chemicals every year, but exposure without eating food is not difficult, considering how easy it is to absorb the chemicals through your skin, and how easily they leach and drift. Clothing readily absorbs many chemicals, and can hold it until it is taken in by your skin. This is especially true of the organophosphates.

The worst result of many of these poisons is that they increase the need for vitamins, minerals, protein and energy while simultaneously reducing the body's ability to gain them from food. A person can suffer from severe malnutrition and be eating all the "right" foods.

When it is considered that the use of these chemicals increases the rate of disease (by encouraging mosquito and other insect-borne disease), decreases nutrition in food and otherwise makes the environment less wholesome to humans, the full implications of the disaster are begun to be understood.

Special nutrition – detoxifying supplementation

Dr. John Kellogg developed the first understandings of how the body poisons itself through autointoxication, and prescribed a diet low in protein, high in fiber, rich in fruits and vegetables and balanced in protein to cure the disorder. However, when the food itself is toxic, or when the body is stressed through severe infection, additional support is required and Kellogg's basic and

fundamental approach is insufficient. Fortunately, Dr. Mark Hyman developed an improvement to the antitoxic diet that is largely effective.

When a human is infected by microorganisms or has been exposed to toxins, it is necessary to support their bodies beyond a normal, healthy, antitoxic diet as they detoxify the pollution in their tissues and blood. While fortified water (as discussed in the chapter on Animal Husbandry – a combination of water, sugar, balanced protein and balanced vitamins and minerals) is a good beginning, specific supplementation will assist the body further.

Three herbs, in particular, are excellent for this. The cranberry fruit supports kidney function by stimulating the kidney to work harder. Other diuretics function similarly, but in America, the cranberry is widely available and affordable. The thistle (especially the milk thistle) supports liver function in a similar way: it provides the necessary chemicals required for the liver to function so that less energy is required to manufacture precursors to those many enzymes that the liver produces and more enzymes are produced. Kelp supports the endocrine system by similarly "feeding" it.

Specifically, and in addition to the fortified water, Dr. Mark Hyman and others suggest that the human should consider supplementing

- Cranberry, Thistle and Kelp
- Vitamin B-12 (which supports every cell in the body, especially affecting the DNA synthesis and regulation but also fatty acid synthesis and energy production. It also helps greatly with muscle growth and development. This should be administered under the tongue or otherways that avoid digestion.)
- Vitamin C (while manufactured by most animals, humans, many apes, many monkeys, many tarsiers, all bats and a few other animals rely on external sources of Vitamin C. Most foods have quantities of Vitamin C, especially vegetables and fruits. It is used in many ways in the body, both as an antioxidant and a prooxidant, almost always as an antitoxin. Notably, it functions against uric acid and other toxins that are byproducts of human meat digestion, though not completely enough to eliminate the dangers of dietary meat, nor does it act upon the dangers of high protein content in the gut. Cooking Vitamin C destroys it, and under normal cooking conditions 60% or more of the Vitamin C is destroyed). The human body requires about 4 grams of Vitamin C during the day.
- Calcium Citrate (which is more readily absorbed and used than other forms of Calcium)
- Choline (a kind of B vitamin necessary for cellular structural integrity and signaling, neurotransmission, and as a source for methyl groups via its metabolite, trimethylglycine). It is especially effective against organophosphates.
- Inositol (which is used throughout the body in insulin signal transduction, cytoskeleton assembly, nerve guidance, intracellular calcium (Ca_2+) concentration control, cell membrane maintenance, serotonin activity modulation, breakdown of fats and reducing blood cholesterol, and gene expression and more).
- Magnesium (which functions as a laxative, reducing the risks of reabsorption through the gut of toxins eliminated through it. It also functions in other important ways, but this is the chief benefit of magnesium in the detoxifying supplemental diet).
- Omega 3, Omega 6, and Omega 9 ("Essential") Fatty Acids (this is easily obtained through flax seed oil, or through most seeds and nuts and grass-fed bird eggs. Omega Fatty Acids are used throughout the body, but especially in neural tissues muscle tissues).

- A general multivitamin

Some poisons require specific antitoxins and a Doctor should be consulted at all times during detoxification. Yet it is a general rule that poisons, whether natural or synthetic, both increase the need of a body for vitamins and minerals while decreasing the ability of the body to use what vitamins and minerals are available by either directly reacting with the vitamins and minerals or by inhibiting their uptake and use.

Fortifications versus supplements: fortification risks oxidization and spoilage of nutrients before they are consumed, supplements are not so easily absorbed in the gut as fortifications

Fortification is supplementary nutrition integrated with food, fortifying or "strengthening" the nutritional value of that food. Supplements are generally nutrients in pill or capsule form that are not integrated with food. Generally, fortifications are made in such a way that would not harm the consumer except by extreme over consumption. There is usually no danger to fortifications. With the right materials, knowledge and skill, it is even possible to fortify food you grow and make.

It is easier to gain nutrition from fortifications than from supplements. Fortifications are absorbed better than pills or capsules because the food they are integrated with pushes the nutrition into the walls of the intestine so they may be more easily absorbed. Pills and capsules may be made easier to digest by dissolving in liquid or into food. That said, pills are more convenient and may be taken without fear that they will oxidize or spoil within the food before they are consumed.

To fortify vegetables, simply soak them in a solution of water and the desired nutrient: within hours, the nutrition will be integrated with the food. If you use food coloring, you can watch as the water is imbibed by the plant (and the nutrition is imbibed with the water). To fortify grains, integrate the nutrition in powder form with the flour, water or oil (if the grain recipe has oil in it) before preparation. Also try dehydrating a nutritious vegetable (such as spinach) and using the powder in your pasta or bread; you can also simply cook the nutritious vegetable into the liquid of the grains (such as in steamed vegetables and rice, or spinach and oatmeal). This vegetable foritification is very effective!

Cooking destroys nutrients; some nutrients improve or reduce the affect of other nutrients

Just be warned that cooking destroys some nutrients, and that some nutrients interact with the other chemicals in the food to reduce or improve the nutritional value of the food (in example, adding Vitamin C to iron-rich foods improves the nutritional value of the iron because the iron is better absorbed, and boiling Vitamin C will usually destroy it). Complete information on fortification fills other books, and these books are easily found at your local library. Also consider contacting your State Extension Service for information, or asking a Professor of Nutritional Science at your local University for more information.

With good diet, fortifications and supplements are not necessary; with good soil and good farming practices, good diet is possible

Neither fortifications nor supplements are necessary with good diet. Malnourishment is rarely seen with a balanced diet. If a person eats well, and if what they eat ate well, they need no further assistance to meet their recommended daily intakes. However, because it is difficult to learn what nutrients a particular plant may lack or have excess of, some prepared foods (especially breads and cereals) offer fortifications to guard the consumer against a lack of nutrition. Thus, it is essential that a farmer grow their own food for their human laborers.

Every plant and animal, being a unique creature, will have a unique constitution. If the soil is healthier, the plants will be healthier and the animals that eat those plants will be healthier and the milk or eggs they produce will be healthier. If there is no iron left in a soil, the plants growing on them will have no iron to give to those who would eat either their fruit or their vegetation. Good soil creates good food, and it is important to learn how the produce was grown if excellent nutrition is to be gained from the food. This said, adequate nutrition can be gained from produce grown on poor soil; it is very difficult for a farmer to deprive their plants or animals of all nutritional value.

Food may be pleasureable, but pleasure is not the purpose of eating: eating is for nutrition and health. Chefs must prepare foods both delicious and nutritious

Food is pleasurable (unless very improperly prepared, preserved or otherwise provided to the consumer). The purpose of eating, however, is not for pleasure: it is the purpose of eating to gain nutrition and to improve the health of the consumer. If you organize your meals with this goal in mind the result will be tasty.

The chef who would prepare the best food is encouraged to research further into human nutrition, plant and animal nutrition, agricultural production, soil science and microbiology. Learning how to feed people best will allow the chef to learn how to prepare food the best, and will require learning how to feed those creatures that humanity depends upon for food best. It will require the chef to learn how their food impacts those who would eat it, both in their mouths and in their guts. With such knowledge in hand, the chef can better prepare food that is satisfying to both the mouth and the body as a whole.

Irregular fortifications such as pain medicine

Pain relief and swelling reduction are sometimes required and the bitter medicine (typically the parts of willow, aspen, cottonwood and other poplars) is difficult to eat or drink as a tea. Thus, they are integrated into food to disguise the flavor. As the popular song goes, "a little bit of sugar helps the medicine go down!"

Preserving food

Preserving food is one of the most important ways to not only ensure availability of food, but also to reduce the costs (or improve the value) of food. Food, once produced or acquired, becomes

more affordable to prepare than to reproduce or repurchase, and food is always more valuable fresh than spoiled.

Proper preservation also reduces the risk of disease and improves the health of those who would eat the food. Proper preservation improves flavor and the nutritional value of food.

There are two goals of preservation: first, to eliminate competition (macroorganic and microorganic) for your food. The second is preventing food from spoiling (chemically decaying).

Protecting your food against macroorganisms

There are countless organisms, large and small, that would eat your food. The food must first be protected against the macroorganisms that would eat your food. Mice, in-laws, ants, bad roommates, squirrels, children and birds are good examples of creatures that might eat your food. There is no sure way of protecting your food against these scavengers, but knowing the behaviors and abilities of them helps: some animals can open jars and others can't, some animals can't reach above a certain height, and others can (or should be able to, at least) read when you put your name on the food item in clear capital letters that say, "THIS IS MY FOOD, HANDS OFF!"



Generally, the best place to store food is in a home or cellar with sealed walls. This prevents most scavengers from even finding the food. However, some scavengers will burrow, tunnel or otherwise force or find their way into the home or cellar. The best place to store food in the home or cellar is in a cabinet that is raised off the floor. If a pest manages to steal your food from a raised

cabinet, there are other ways of securing your food, including sealing the food in a container (such as a jar or can) or locking the cabinet. If the pest continues to be a problem, consider employing a cat, lizard, ferret or other hygienic carnivorous house animal.

Constructing a cellar is easy: dig a hole in the ground, fortify the sides and floor with concrete or wood to prevent cave-ins and keep soil and burrowing animals out, and attach a door to the top. Cellars that are deeper remain more temperature stable through the year and preserve food better. Locks on the door prevent some animals who understand how to access doors from getting in.

Many flies will try to eat your food. In doing so, they spread disease: not because flies are dirty (they are some of the cleanest animals on the planet) but because they spit on your food to digest it. Whereas humans apply saliva in their mouths to their food, flies must apply spit outside of their straw-like mouths: this way, they can suck up the food.

The potential of flies to poison you does not make them "bad." Many flies are essential pollinators: without their help, you wouldn't have much food to worry about protecting! Do not try to kill the flies. First, you can't possibly succeed at your genocide. If someone somewhere had figured out a way to kill every last fly, they would have been eradicated long ago. Second, it is more effective to simply remove your food as a temptation to them. They would rather eat your food than their natural foods, and if you protect your food from them – and other macrobiotic creatures – by exercising proper food storage techniques, you will more effectively protect yourself than if you attempt to kill the flies: you will never kill all the flies, and never before some of them eat your food.

Protecting your food against microorganisms

Once the food has been protected against macroorganisms, the food must be protected against microorganisms (such as bacteria, fungi, viruses, retroviruses, etc.). These microorganisms typically produce toxins while eating your food that are poisonous and render your food inedible. They are also much, much more difficult to defend against than macroorganisms.

All animals that store food practice some form of food preservation against microorganisms. Bees encase their food in wax: this is similar to what people do. Everything from apples to your favorite jellies are sealed with wax to keep the food air-tight. Some foods are encased in chocolate – a wax-like substance. Foxes will bury their surplus food underground in almost air-tight conditions. Removing the air removes the necessary atmospheric chemicals required for the microorganisms to eat and live.

But besides keeping food air-tight, it is important to keep the food dry and cool: microorganisms need water to eat and live and warmer temperatures increase the speed at which microorganisms eat and reproduce. Freezing food does not actually prevent microorganisms from eating or reproducing, but it does slow them down considerably. Some birds will store their surplus food in granaries (like people do) made of hollowed out tree trunks. A smarter scheme is to dehydrate food for storage. It is one of the best – if not the best – way to preserve food at room temperature or at any temperature.

Refrigeration is an excellent technique for protecting your food. Refrigeration cools the microorganisms and reduces their activity. Food, depending on its freshness and cleanliness at the beginning, can last anywhere from a few hours to a month or more in the refrigerator: hygiene improves the effectiveness of refrigeration. Food that is washed has fewer microorganisms than food that is unwashed. Produce, especially, should be washed daily. Clean your refrigerator weekly. If

you are using a root cellar – an underground room that is kept cool because of its depth into the ground – line the walls and the floor with material that is easy to clean, such as tiles or painted wood.

Refrigeration can be made even more effective by preventing the microorganisms from breathing. Store your food in an airtight container (such as a bag, jar or can). This reduces the air available to microorganisms for breathing and slows their already slowed activity more.

Refrigerating infected produce is unsanitary as it may infect other foods. "When in doubt, throw it out" is a good phrase to work by, when refrigerating or when storing food in an unrefrigerated location: as soon as evidence of microorganic activity is noticeable, the food should be discarded in such a manner that it is inaccessible to children and domestic animals. This way, the infected food does not infect other food in the storage location, or risk being accidentally ingested by a member of the household that is not aware of the infection. By the time you can see the infection, it is already too late: colonies of microorganisms that have flourished enough to become visible to the naked eye have already long ago started polluting your food with dangerous toxins.

Prevent infection by maintaining the sterility of the storage location and container. This is why it is important not to drink juice or milk out of their cartons: doing so introduces many microorganisms into food that otherwise could have remained free of them.

If refrigeration is not possible, use antiseptic spices (such as pepper, salt, cinnamon, juniper berries, etc.) to protect your food: if used properly, these can even preserve milk unrefrigerated for many days! You can also employ beneficial microorganisms (as described later in this chapter) to defend your food for you.

Do not preserve decayed or spoiled food

Preservation works better if the food is not already spoiled. Examine food for signs of infection before acquisition. Avoid foods that have been grown in dangerous media (in example, salads grown using raw animal manures as fertilizer present an unnecessary risk of E. coli).

A common mistake is to attempt to preserve lettuce that is already rotting. Lettuce turns red at the base because of bacteria. These bacteria release toxins into the food—even into the parts that are not red. The time the lettuce turned red at the base was the time to cull the lettuce from the refrigerator—not introduce it into preservation. In the same way, cheese or bread that has mold on one side of it has toxins throughout the entire block or loaf and should not be preserved but thrown out. When things that should be firm become soft, when the food no longer smells "fresh," when there is ANY evidence of decay, the food should be THROWN OUT.

Food poisoning from spoiled food is dangerous. Some fungi produce toxins that are fatal. Life is not worth the cost of the "clean" half of a block of moldy cheese, nor the "good" slice or two of bread on a spoiled loaf, nor the few "fine" leaves of lettuce on a spoiled head.

When in doubt, throw it out. Decayed food that is consumed is more costly to you than the decayed food that is thrown out: disease and death, and the results of disease and death, cause long-term and costly decreases in the productivity and health of the household. Eating poison is less good than eating nothing.

Long-term preservation: dehydration is best, canning also works, spicing food works better than canning

Refrigeration is great for short-term preservation. For long-term food preservation, there are many methods to choose from. Dehydration is an excellent method of food preservation. It does not require great skill or expensive equipment—even if it does take some time. While you can dehydrate food outdoors, the weather is sometimes uncooperative. Try using dehydrating machines. Dehydrators can be purchased for a minimal cost and are nearly risk-free.

A dehydrator may, with little difficulty, be manufactured at home. A home-made dehydrator may be as simple as a large box with holes in the side for ventilation and a hairdryer or fan inserted through a hole in the lid. The USDA Garden Bulletin 217 (Drying Foods at Home) includes plans for building a sturdier, larger and more complicated electric food dehydrator but good results can also be had by using a household oven or toaster oven on very low (less than or about 100 degrees Fahrenheit) heat, or by putting food between two screens and covering them with an insect net before putting it in the sun outdoors. Just make sure that air can circulate around the food, or otherwise the food will not dry uniformly and may rot. Cutting the food into small, thin pieces helps this process. Practice improves the results.

USDA bulletins are listed by title and may be downloaded at http://www.nal.usda.gov/ref/USDApubs/hgb.htm#sortnbr

Dehydration works by removing the water the microorganisms rely upon to grow. Without water, they die or hibernate; in either case they do not produce toxins dangerous to the consumer of the food. After the food is dehydrated, you may store it in a clean jar, can or bag.

We will emphasize that the goal is not to rid food of microorganisms, but prevent them from making your food toxic with their wastes.

Dehydration—and all food preservation—reduces the nutritional value of the food, but dehydration damages the nutritional value less than many other types of food preservation. Store bought dehydrated foods (i.e. raisins, currants, etc.) are often as good as home-dehydrated foods. Try dehydrating your potatoes or summer-squashes, and using them in soup! Unsalted, unoiled zucchini or potato chips are also a delicious alternative to oily, salty potato chips. Try dehydrating celery for a delicious herb, or preserving other foods before they spoil for use another day.

It is important to keep your dehydrator or dehydration space (if outdoors) clean against microorganisms: sanitize by thoroughly cleaning with soap and water regularly.

Food may also be preserved for a long term by freezing, though the food's preserved lifespan is limited to between six months and one year. Microorganisms will still grow in even sub-zero degree (Fahrenheit) temperatures, producing dangerous toxins. It is very important to sterilize the container the food is stored in and constantly check for infection. Freezing retains much of the flavor and nutrition of the food, but will damage the texture: freezing destroys the cellular structure of the food, and this affects both nutrition and palatability. Store-bought "freezer section" frozen foods often have too much salt to be considered very nutritious. If you are freezing your own food, remember to keep your freezer as clean as your refrigerator!

Another way to preserve food is to can it. A significant danger to canning is not sterilizing the can enough, and a resulting Botulism or other microorganism infection. Because infection can occur, be sure to check for infection before consuming. Canning retains all the nutrition of the food (in either the canning liquid or the food itself), but if the liquid is not used upon preparation of the preserved food, much of the nutrition is lost (the water-soluble nutrition will leach into the canning

water, and fat-soluble nutrition will leach into the canning oil). Store-bought canned goods are often safe to eat.

Canning is a complicated process. The food must be cooked and sterilized, and put into a sterile container, sealed shut without air. The jar is filled with the hot food, and as it cools, it creates a vaccume that holds the lid on very tight. Food is treated with salt (to make "pickles") or sugar (to make "preserves") to further inhibit microorganism activity.

Some foods are spiced to preserve them. The use of cinnamon, black pepper, or other acidic spices can preserve food fairly well. Besides spices, consider placing foods in raw milk or other foods that are naturally antimicrobial.

Use of beneficial microorganisms for food preservation, discussion of pasteurization

There are some situations when you want your food infected with a desired type of microorganism, and in these cases the goal of preservation is to prevent undesired secondary infections. An example is the fermentation of bread by yeast, when you must infect the bread with the friendly yeast and prevent a secondary infection of bad microorganisms.

Other situations usually involve dairy foods and result in a pasteurization of the food. Pasteurization was invented by Louis Pasteur. Pasteurization is a process of bringing the dairy to a temperature at which the microorganisms in the dairy die (usually 145F for up to 30 minutes, 161F for 15 seconds or 275F for a fraction of a second). Though such temperatures would normally cook the dairy, pasteurization occurs so quickly that the dairy remains uncooked...mostly. Some nutrients are cooked, and pasteurized milk has 25%-38% less Vitamin B, 20%-50% of the Vitamin C, and much less Vitamin A than unpasteurized milk does. This is why Vitamin A is usually added back into pasteurized milk. There are also negative effects of pasteurization on the protein and other nutrients in the milk. Also, pasteurized milk is freed of not only the bad microorganisms, but also of the good microorganisms that the body relies upon for safe digestion of all foods.

There are arguments against pasteurization. Not only does it reduce the nutrition of dairy by destroying some nutrients (especially vitamins) and kills the microorganisms that the body relies upon for safe digestion of all foods (especially the acidophilus bacteria), but that it does not kill all the bad microorganisms. These claims are true, and also raise concerns of pasteurization-resistant microorganisms (microorganisms that don't die upon pasteurization). However, unpasteurized "raw" dairy also is not perfectly safe.

Concerns of a lack of nutrition in milk are equally ill-founded: the lost vitamins and proteins are regained through a balanced diet that includes fruits and vegetables, and the bacteria needed for safe digestion may be added back into the dairy, or directly implanted into the human body either by consumption (of a pill or tablet) or through enema.

Because the evidence that dairy is best preserved by pasteurization is significant, proponents of raw dairy attempt to demonstrate that with adequate safety precautions, raw dairy may be as safe as pasteurized dairy, and that, nutrition aside, the flavor of raw dairy is superior to pasteurized dairy. Yet there may come a time soon when pasteurization-resistant microorganisms give new arguments to the proponents of raw dairy.

No arguments will be made here favoring either raw dairy or pasteurized dairy, but words must be said on role that the microorganisms in raw dairy play in the preservation of the food. As said previously, in raw dairy there are good microorganisms that may be, often, relied upon to protect the consumer against the bad microorganisms in the dairy. The good microorganisms

produce toxins that are harmless to people, but deadly to the bad microorganisms that would produce toxins harmful to people. Some of the safest dairy products rely on both pasteurization and the reinfection of the dairy with these good microorganisms.

If pasteurization is to be attempted at home, remember that it is important to both keep the pasteurization equipment sterile and the receptacle of the pasteurized food sterile. The more sterile, the longer the food will be preserved. Also, if possible, reduce the oxygen in the atmosphere in the receptacle: oxygen will still cause the dairy, juice or other pasteurized food to become rancid—even if there are no microorganisms, whatsoever. Many professional companies pack the food under nitrogen for this purpose. Without the equipment of these professionals, home-pasteurizers should aim to reduce the air in the receptacle, as with normal canning.

Many cheeses rely on good microorganisms to pollute the dairy with poisons that are non-toxic to humans, but very toxic to bad microorganisms.

Chemical preservatives: salt, sugar, oil, Vitamin C all safe chemicals

Another way to preserve food is to place it in a chemical.

Sometimes that chemical might be a salt or a sugar. Salts and sugars absorb free water and make the food deadly to microorganisms: with the salt or sugar, there is not enough water for the microorganism to live or else the food becomes so acidic or basic that the microorganism cannot live. Some popular salts include table salt (Sodium Chloride), vinegar or Vitamin C. Popular sugars include not only table sugar, but also fruit juice (especially lemon juice, whose high-acid pH is antimicrobial). Often a food will be canned and then salt and/or sugar will be added to the water in the can for extra protection against spoilage.

Sometimes that chemical might be an oil. Oils are used to reduce contact with the air so that microorganisms living in or on the food cannot breathe. One of the most ingenious methods of oil preservation is the coating of foods in chocolate (such as the chocolate-covered peanut or cherry)! Olive oil is a delicious way to improve canned food safety.

Other dangerous and safe chemical preservatives

But there are other chemicals to preserve food with, too. You might encounter strange chemical names when examining the ingredients of store-bought preserved food. Most often, these chemical additives are for the preservation of the food. What are these mysterious substances? Where do they come from? Are they nutritious or poisonous upon ingestion?

BHA & BHT: These complicated molecules are used to stabilize oil to prevent rancidity, and are used in everything from salad dressing to cereals. However, if you're curious as to what its effects on the human body are, you're not alone: it is still unknown. Even the Food and Drug Administration, which regulates the use of BHA and BHT, is uncertain.

Calcium Chloride: This salt is commonly found in foods advertising "no salt," because it is not, strictly speaking, "table salt." Do not be fooled! Calcium Chloride ($CaCl_2$) is salt—and a more powerful salt than Sodium Chloride (NaCl). Calcium Chloride when digested yields good calcium for the body, but this is hardly an advantage: Sodium is also required for healthy bodies, and when Calcium Chloride is used, Sodium is not. Also, there is some argument that the extra Chlroine could bring the daily intakes too high: with Calcium Chloride, the consumer gains twice as much Chloride

and will exceed their RDA maximum (3.6 g for an adult) easier. That said, it is largely harmless, and some people prefer the taste of it to table salt.

Calcium Chloride is created by dissolving limestone (Calcium Carbonate) or marble in Hydrochloric acid. It is "generally recognized as safe" for consumption by the USDA, though ingestion of pure Calcium Chloride is dangerous (causing gastrointestinal irritation and ulceration, nausea and vomiting). Then of course, pure table salt isn't so good for you, either.

Calcium Chloride is used to preserve the texture of foods, as well as in place of salt to extend the life of preserved items. It can do this because of the Calcium, which strengthens the tissues it is absorbed into.

Carrageenan: This chemical is used as a thickener and to change the texture of some foods. Some studies have shown it to be carcinogenic, but the FDA refutes this claim. In any case, it is a gum (see below) and these are no good for you.

Gums: There are many gums used in a wide variety of foods (even "fresh" fruits and vegetables as a coating!), including guar, xanthan and locust bean. They are also used to affect the texture and to emulsify foods. They are most likely non-toxic, but have been shown to affect digestion by increasing bile production and preventing the uptake of some nutrients. Eating food is supposed to provide nutrients, and preventing uptake is a problem. Gums are used in preservation in a poor imitation of oils, which are nutritious.

Nitrates: Nitrates are used in combination with table salt in the form of Sodium Nitrate. Sodium Nitrate is used to fix color and prevent microorganic activity. Yet nitrates can interact with amines (a type of protein) to produce Nitrosamines, which are cancerous. Other interactions of nitrogen-based preservatives are unclear.

Phosphoric Acid: This acid is used not only as a preservative, but as a food flavoring. It is made by applying Sulfuric Acid to Calcium Phosphate rock. It is a dangerous chemical: phosphoric acid has been shown to strip calcium from skeletal tissue, causing osteoporosis. Phosphoric acid is usually found in soda (in case you needed another reason not to drink soda!), but pops up here and there in other foods.

Silicon Dioxide: This chemical is used as a filler or carrier in a variety of foods, from spices to beverages. The FDA says it is "non-toxic, odorless, and chemically inert." It is, basically speaking, sand.

Sodium Phosphates: It is primarily used in dairy to stabilize the proteins and buffer the pH for safety and flavor. Sodium diphosphate is a weakly bound chemical which breaks apart during digestion.

Sulfates: Sulfurous compounds are used in a variety of forms to prevent discoloration and oxidation of fruits and vegetables. They are also used in numerous foods to prevent rust discoloration caused by rusty boilers, and also for the bleaching of foods. Sulfates destroy Thiamin (Vitamin B1) and should not be eaten at the same time as Thiamin if the Thiamin is to be absorbed.

Herbal preservation

Some herbs are excellent food preservers. Rosemary, sage, cinnamon, black pepper and other herbs have been used for hundreds or thousands of years to preserve food. You sometimes see these herbs rolled into or around cheeses or in oil-based salad dressings because they stabilize the oil from becoming rancid and reduce or sometimes prevent microbial activity. Sometimes you might see black pepper, lemon, cayenne or other acidic herbs used in the preservation of fruit. These herbs

work because of their chemical structure: some herbs are highly acidic or basic, some are salty or sugary...herbs, and all foods, are simply chemicals. When used appropriately, herbs can be as healthful as artificial nutrients; when used inappropriately, they can be as dangerous as artificial poisons.

Radiation and sonic preservation

It is possible to sterilize food without adding any chemicals to it. The use of Ultraviolet, Infrared, Visible-Spectrum, Microwave, X-Ray, Electrical Field Pulse, Electromagnetic and other radiation is even more effective at sterilization than chemicals. A drawback to some radiation is that it only sterilizes the surface of food. Other radiations can penetrate all the way through a food.

Radiation is typically used at great intensities (about 20,000 times brighter than sunlight). Electromagnetic energy is typically used at about 108 MHz. Electrical Field Pulses are generated at about 10-50 kV/cm.

Unlike chemical preservatives which both inhibits microorganism activity and sometimes kills the microorganisms, radiation aims only to kill the microorganisms. Some damage to the food is possible through both chemical and radiation treatments, though the "damage" is sometimes desirable with chemical treatments (altering the food's flavor with herbs, or the fermentation of cheese, for example). Both chemical and radiation treatments reduce or alter the nutritional value of food: there is no way to ensure that all the nutrients are intact except to eat food fresh, within seconds of harvest. As soon as food is harvested, it begins to decay.

Preserving canned and dried foods

Each preserved food has different needs for storage conditions. Many canned goods and many dehydrated goods need only to be stored at proper temperatures. Yet some foods (such as flour) need further work: flour should be stored in a cool, airtight, clean place. This prevents the flour from turning rancid or becoming infected by microorganisms.

Flour has oil and all oils will become rancid without the action of microorganisms: this is a decay of the lipid which occurs when the lipid has contact with the air or that may naturally occur with time. Rancid foods are not dangerous to people, even if they taste disgusting.

Raisins and other dried goods without much or any fat content, while not needing very specific storage conditions, remain moister and tastier if kept in an airtight container. Yet very dry raisins are just as nutritious as "moist" raisins.

Every food has specific needs for preservation and if in doubt, ask neighbors, government officials, university Professors, chefs or other knowledgeable persons in your community on how best to preserve the food.

Preserving food left over from a meal

Leftovers should be divided into two categories: those that will be consumed in the short term (three days to a week) and those that will be consumed in the long term (six months to a year or more).

Short term leftovers should be stored in a clean, airtight container and refrigerated. If possible, the container should be changed every day for a clean one. This helps prevent microorganism infection while also reducing the risk of the food turning rancid.

Long term leftovers should be preserved by dehydration, canning or freezing.

Selecting fresh foods

Though the farmer will probably grow their own fresh foods, it is possible that they may not, and likely in any case that they ought to know what consumers look for when selecting fresh foods.



Where is your food coming from? Is it fresh?

Food has more nutrition when fresher, avoid decay; fresher foods taste better too; food preservation is about reducing the risk of spoilage

Produce has more nutrients and flavor when fresh. This is because decay, a process by which the nutrients are either destroyed or poisoned, begins and progresses as the food dies. From the time

that the produce is harvested, it begins to decay. Some produce, such as onions, are still alive, but dormant. These living foods decay slower than foods, such as asparagus, which are dead, because their immune systems are still functioning.

How do you tell if the food is still alive? Besides learning a little about plant and animal physiology, you can ask the question of whether the produce would grow if put back into its natural environment? An egg would not continue to grow, nor would a head of lettuce harvested without its roots. A head of lettuce harvested with its roots would grow, as would a potato.

Deciding if the food is alive gets more complicated when the time it takes for the food to die is considered. Celery stalks, while not able to live, will still act alive (pulling water up from the basin it is kept in, for example) for a little while because the dismembered plant has not yet wholly died.

Many foods can be harvested so that they are still alive by the time they are bought or consumed: every product, from milk and eggs to asparagus and strawberries can be harvested and brought to market in an "alive" condition. However, for the safety of the consumer (as in the case of dairy being pasteurized) or for the financial cost of making the food available to the consumer in an alive condition, most food available in markets is not alive. The best way to secure the freshest food is to grow it yourself.

Yet, even if you do not grow it yourself, you can still select food that is less dead, less decayed, and, sometimes, alive and healthy. Decayed foods are usually poisonous. The microorganisms that undertake the decay produce toxins that are dangerous for human consumption. As mentioned in the previous chapter, these foods are not to be preserved or eaten.

It is very important that the ingredients be within the expiration date and not rancid or spoiled. This effects the flavor! Shelf life, the time a food will remain acceptably free of spoilage, is important for taste and good health. Old food not only tastes wrong, it can be less nutritious and dangerous to eat!

Spoilage includes staleness, rancidity and infection from microorganisms like bacteria and fungi. It includes chemical changes to the food from oxidation.

Spoilage, of course, is not limited to items past their shelf life. Improper storage, improper preparation or other factors can cause it to happen.

Spoilage is a gradual process—it does not happen instantaneously. It is a progressive change: at first, the food degrades slowly, or the bacteria population is miniscule. The spoilage increases over time until it becomes noticeable, then intolerable. But it is important to remember that at any time during this gradual process it can be dangerous.

Infection, including rot and molding is the easiest to see. In this case, something is eating your food! While this is bad enough, these microorganisms sometimes produce waste chemicals that are very toxic. Or, they are harmless enough but they attract other predatory microorganisms that release toxins.

Bacteria, viruses and fungi are quick to take hold whenever and wherever they can. And freezing food does little against them: many of these creatures continue to eat and poison your food even at sub-zero temperatures (though they do so more slowly)!

At first you will not be able to see them without a microscope, but as their populations boom, their colonies can be seen with the naked eye as spots, blotches, fuzz, or felt with the fingers as soft areas, or detected with the nose by their foul odor.

By the time you can see the little critters, they have likely spread throughout the food in invisible quantities (after all, they were there in the spot now visible before they multiplied enough to become visible!).

Some infections never become visible, smellable or touchable.

When you see them, throw it out. If in doubt of whether you see them, throw it out. Cutting mold off won't get rid of the infection and could get you a trip to the hospital. Food poisoning is most often the result of eating foods that are spoiled after thinking that the spoilage was limited to a part easily cut off or that are "still ok."

Ineed, preventing the infection of food by undesired microorganisms is about reducing spoilage, it's about keeping food fresh. Antimicrobials and microbial inhibitors are used in many processed foods but never work all of the time. Traditionally, spices have been used to prevent spoilage. Excessive quantities of black pepper, cinnamon, cloves, sugar, and other flavorings not only disguise the flavor of spoilage, but actually inhibit microbial action by making the food acidic, dehydrated or otherwise unpalatable and inhospitable to the microorganisms that would eat it.

As mentioned before, not all microorganisms are bad, and many (like the acid-loving bacteria that make your favorite yogurt, cheese, alcoholic beverages and other treats) preserve the food in much the same way as spices do: they produce acids that the bad microorganisms hate.

These good microorganisms live naturally in your gut and, along with more active friendly predators, provide your very first line of defense against most of the bad microorganisms that are either trying to eat your food or eat you.

You get many of these beneficial microorganisms into your gut through your food: by sharing a similar taste in food, a beautiful friendship develops. You also got many of them when you were a baby from your mother's milk.

One way to help these friendly gut microorganisms is to eat the foods they like: sugary, fibrous foods (whole grains, fruits, vegetables and dairy) and avoid the foods that feed your mutual enemies (protein rich foods like meat).

Suspect all food, even that which you grow. Especially, "buyer, beware!"

Just because you are told the food is fresh does not mean it is so. Even at farmers markets the food should be under suspicion. Even the food out of your garden should be suspected! Inspect all your food before purchase or harvest.

Food that is unrefrigerated at the market or put on display in the hot summer sun is highly suspect. These foods are not preserved and will decay faster than if they had been properly cared for and are, most likely, not good to eat.

Also highly suspect food kept in water for "freshness." The authors have seen rhubarb and other vegetables kept at the farmers market in water to prevent wilting. At one market, the authors, upon investigation, learned that the vegetables were kept in filthy water, reused from previous markets, in filthy containers, never washed or sanitized. As these still-living plants attempted to stave off wilting, they sucked the water up into their stems to avoid wilting and, in doing so, brought the filth into the mouths of whoever purchased them.

And, just because the produce looks alright does not mean it is so: study the habits of your grocer, and it is likely you will see them trim off decayed stems and leaves of cabbages and lettuces, or pluck a moldy berry from a package (leaving the rest on the shelf). The remaining berries are still infected by the mold, and the lettuce has still imbibed the poisons of the infected stem and leaves.

To be able to identify fresh or spoiled foods, study pathology; what foods to refuse

To select the freshest foods, the consumer must become an expert in pathology, being able to identify various forms of decay. Mold, viruses and bacteria produce changes to the texture, smell, flavor and appearance of the food on which they grow.

Would you purchase broken eggs? Refuse wilted produce, or produce with infected bruises or other wounds (especially notice where the lettuce and other vegetables were cut from the rest of the plant: if you notice red or other discoloration, this is a good sign of bacterial infection. But, even if lettuce is not red, it might have been trimmed by the grocer so that it does not look red! Look for other clues beside the stem, such as the ribs in celery or the wilting of the lettuce leaves).

Refuse produce that has slime on it.

Refuse produce that is soaked in dirty water.

Refuse moldy produce, or produce kept near mold. One bad apple spoils the bushel.

If you notice the produce is not being preserved under good conditions (if it is not refrigerated, or not kept moist enough to prevent wilting) and the produce is not yet damaged from its maltreatment, it is your choice whether to risk the purchase of that produce. You chance your life and your health.

Even produce just picked is at risk of disease: if the plant is infected in the field, it needs no help from poor preservation to become dangerous for consumption. Be vigilant as you harvest!

In preservation, the rule is, "when in doubt, throw it out." In selecting food, the rule is, "when in doubt, go without." Eating nothing is better than eating poison, and it is possible to survive the whole winter without fresh produce, eating a balanced and nutritious meal every day. This reality is made possible not only to skill in preservation, but also, in large part, to the fortification and supplementation of nutrition in food.

Digesting food: eat for your friends; how to encourage beneficial microorganisms in your gut so that you are healthier – the human body relies on microorganisms for immune response and digestion, among many other services

Microorganisms include bacteria, fungi, viruses and protoviruses. Some are helpful, or "good," while others are harmful, or "bad." Without good microorganisms, the human body could live, but with them, the human body lives longer, healthier and stronger. Among the many services the good microorganisms provide to the human body, the two services that impact nutrition most are that they are the human body's first line of defense against "bad" microorganisms and that they help the human body digest food safely and efficiently.

Microorganisms live everywhere on and in your body. On your skin, they protect you against the bad microorganisms that would eat you from the outside in, feasting on your flesh or boring through your skin to the sweet blood and organs inside. Inside your body, they live in lymph nodes, in blood, and in all your organs and tissues. Some of these good microorganisms eat the bad ones, others produce chemicals that inhibit or prohibit the growth of bad microorganisms. But these good microorganisms are not anywhere more important than on the outside surfaces of your body: your skin and digestive system. Yes, your digestive system is an outside surface of your body, even if it is hidden from daylight: a thin tissue separates your insides from your outsides to form a tube within you that finds one opening at your mouth and the other at your buttocks.

These good microorganisms are so important that human mothers protect their babies by infecting them with these beneficial microorganisms through their milk, through kisses, hugs, and other forms of touch. Humans are not the only mammals or animals to infect their children: most creatures rely on their own good microorganisms just as humans rely on theirs. Some of the most beneficial microorganisms are bacteria, and the most beneficial of these (the acidophilus) are even added to some foods as fortification!

Unsurprisingly, what you eat affects the microorganisms in your stomach. While some of them eat the bad microorganisms, most of the good microorganisms rely upon you to feed them so that they can produce the chemicals that inhibit or prohibit the growth of bad microorganisms. The good microorganisms prefer lots of sugar and lots of acid; the bad hate acid and love protein. The best part is, as the good microorganisms eat their sugar, they produce acid and kill the bad microorganisms.

The bad microorganisms, as they eat protein, produce numerous toxins, which, like the food in your gut, is absorbed first into your blood and then into your various tissues and organs. Your body is always trying to clean these toxins up, and when the body cannot keep up, disease occurs. This disease is called "toxemia." Toxemia manifests itself in numerous symptoms: arthritis, hardened arteries (the body's defense to reduce the number of toxins entering the muscles and organs), insanity, depression, physical destruction of brain tissue, cancer, liver spots, asthma...you name the disease, and it is, likely, just a symptom of toxemia. Toxemia reduces life expectancy by decades: a human who has not suffered from toxemia in their life may easily expect to live more than 120 years. It is a shame that people die so early (the average life expectancy for humans in the United States hovers in the upper 70's) from a preventable disease. Toxemia reduces the endurance of even the best athletes by acidifying their muscles faster than would otherwise occur and cripples even the smartest person's ability to think.

Curing and preventing toxemia by an anti-toxic diet

The best method to prevent the onset of toxemia is to help the friends in your gut that battle your enemies every day: feed them well, and you will have less toxins to eliminate from your body and be healthier. Curing toxemia is preventing toxemia: simply eat better, and the symptoms will go away and your body will heal. And, if you eat well, you will necessarily be eating in such a way to clean your blood of those toxins even faster! You will be defecating three times a day (anything less is constipation) and urinating frequently so that the color of your urine is clear or very pale yellow.

THE ANTI-TOXIC DIET

1) Eat little protein, and eat quality protein. This necessitates the elimination of meat from the diet: meat is just about all protein, and has very little or no nutrients. If you are to keep your protein levels low and still get the necessary levels of vitamins, minerals, carbohydrates, etc. you cannot afford the space in your stomach or calories in your diet to eat meat. A protein supplement may be necessary for those who cannot access a variety of protein sources, but anyone eating more than one kind of food wil likely obtain enough of all the proteins necessary. Nuts and eggs provide superior protein to the diet.
2) Eat much fiber. It is difficult to get too much fiber in the diet. Sugar is important for the good microorganisms, but simple sugars are ingested by your gut very early: some are even absorbed in the stomach! This is why it is important to eat fiber from plants: these complex sugars do not digest so easily and survive to feed the good microorganisms in your intestines. Fiber is also necessary for you to digest other nutrients, too. Without sufficient bulk pressing the food against your intestine walls, you will not ingest nutrients so well as with insufficient bulk. The foods people are designed to eat consist largely of indigestible sugars (fiber) which not only helps us eat, but provides food for our microorganism friends.
3) Eat laxative foods. You should be able to pass one meal from mouth to buttocks in less than 24 hours, and defecate three times per day. This keeps the food from fermenting in your gut and gives bad microorganisms little time to produce toxins. The good microorganisms can eat quicker than the bad, and you can eat quickest of all! Defecating regularly also keeps your gut clean: many people who are constipated have immense quantities of old poop filling up their intestines, coating the walls and preventing the ingestion of food while producing deadly toxins for the blood to take up. Your body absorbs nutrition fast, your friendly microorganisms faster. There is no need to keep food in the gut to feed your slower enemies.
4) Drink water. You need water not only to digest food, but for all your organs and tissues to function well; you need water for so many things, especially for the elimination of toxins from your blood. While it is better to avoid getting toxins into your blood, drinking water will help protect you if some toxins do get into your blood. Water is the most important mineral in a person's daily diet. Urine should be colorless or just noticeably yellow: dark urine is a sign of dehydration.
5) Get plenty of exercise! Exercise not only is good for your organs, but stimulates appetite, encourages your organs to clean your blood of toxins, makes defecating three times per day easier by relaxing the mind, increases oxygen flow to the brain, reduces the risk of heart disease...exercise is what the body is designed to do. Humans are meant to climb, jump, run, dance, throw and catch balls (even as other monkeys and mammals do), sing, stretch and play in all sorts of ways. If you are sedentary, you will not move food from mouth to buttocks as fast as if you were active. Being active is easy! You can get a lot of activity into your day, even if you only spend 10 minutes at it. Try to spend your leisure time moving instead of sitting. If you grow your own food, you are likely getting some exercise, if you dedicate yourself to a sport you are likely getting some exercise. Even meditation and praying can be brought into a type of exercise (think only of the Yogis or Whirling Dervishes). Throw out the television: it is not only bad for your mind, but bad for you body (to sit in front of).

6) Avoid poison. Do not eat poisons: this only increases the burden upon your body. Why would you attempt to reduce the toxins produced by bad microorganisms if you are only going to add them on your own? While caffeine, alcohol, nicotine, and other drugs may have medical applications, do not eat them regularly. Avoid hot peppers, mustards, vinegar, and other foods which are so acidic as to cause ulcers in the gut. Avoid salt: there is usually enough salt in everything you eat already. Avoid most preservatives: while some are generally safe, many can slow digestion or may even cause cancer (for more on preservatives, refer to Chapter I).

7) Eat enough, not to satiety. Just because you are full or still hungry does not indicate whether you should eat more or less. Follow dietary guidelines.

8) Chew your food. Saliva is a very important step in digestion. Even chew your milk, your juice and other liquids! Saliva breaks down food and allows food to be better digested in the stomach and intestines.

9) Eat regularly. This trains your body to a rhythm that is easy for it to keep. It is best to eat three meals per day: a small breakfast, a large lunch and a light dinner. Do not go to sleep on a full stomach: this will discourage you from moving your food very fast through your gut. You should eat little to no protein in the morning: breakfast is the time the body needs carbohydrates. Lunch is the time for protein: you give yourself the most time before sleeping to quickly move proteins from mouth to buttocks.

10) Drink a cup of water upon rising in the morning, before sleeping at night, and an hour before each meal and two or three hours after eating a meal. This aids digestion and helps regulate blood sugar, among many other things.

11) Brush your teeth. Just as you wash your body regularly for hygiene, just as you defecate regularly for hygiene (to keep your gut clean), brush your mouth for hygiene. Healthy teeth are a bonus: these are required for digestion.

12) Beware the harmful affects of antibiotics. While a doctor may prescribe antibiotics to kill one type of microorganism, be sure to take extra good care of your friendly microorganisms during and immediately after the antibiotic prescription. Good nutrition is the best defense against illness, and if an antibiotic is prescribed, it is potentially dangerous if you allow the beneficial microorganisms to suffer along with the bad. If taking antibiotics becomes necessary, question your doctor about all the microorganisms that the antibiotic may affect, and request a narrow-spectrum antibiotic whenever one is available for your disease.

13) Avoid caffeine, alcohol, tobacco and other drugs. While tobacco smoke provides an excellent enema in case of constipation, and moderate consumption of caffeine, alcohol and tobacco can be beneficial, no consumption of caffeine, alcohol and tobacco is better.

Eating more and better with less money

Good food necessarily does not cost as much as poor food: the foods that are best for humans to eat are the cheapest to produce and, because of the demand for those foods which are best for humans to eat, the competition for market share keeps producer's prices low and their efficiency of production high.

Begin planning your meals for the day with the recommended daily intakes in mind. Don't forget to adjust your intake based on your activity! As soon as you know what nutrients you should be eating (or, if you are using the general guidelines, what food groups you should be eating), begin to plan out meals that meet your requirements. You can find detailed information on the nutritional value of almost any food at the USDA's website: www.nal.usda.gov/fnic/foodcomp/search.

Then determine the cost off the ingredients for your meals.

If the cost of the ingredients for those meals is within your budget, you do not need to change any of your menu. If the cost of the ingredients for those meals is not within your budget, determine the amount by which they are not within budget; if the cost is within budget, but you still want to reduce the cost of your food, determine by how much you want to reduce it. You can then begin the process of substituting one cheaper ingredient or menu item in place of a more expensive one.

For example, you typically require 5 – 9 servings of fruit every day. To meet this requirement, you can choose an expensive fruit (such as strawberries), or an inexpensive fruit (such as dried grapes - raisins). Another example would be whole grains: you typically require 6 – 11 servings of whole grains every day. An expensive choice would be to purchase bread, a less expensive choice would be to make your own bread, and one of the least expensive choices would be to eat oatmeal.

But what if you are attempting to meet your nutrient needs, rather than general guidelines? For the sake of clarity and brevity, all other nutrients except iron will be ignored. Your five year-old is attempting to design their menu for the day. They read that they require 10 – 40 mg of iron during the day. In this example, your five year-old can choose only between rolled oats and white whole wheat flour. If we were considering other nutrients, it would be important for the child to weigh how well oats or wheat meet (or don't meet) their need for balanced nutrition. However, it suffices to know that rolled oats have 1.7 mg of iron per serving (0.5 cups) and white whole wheat flour has 1.16 mg of iron per serving (0.25 cups). Rolled oats cost, in this example, $0.11 per mg of iron (assuming a container with 30 servings costs $4), and white whole wheat flour costs, in this example $0.06 per mg of iron (assuming a bag of flour with 75 servings costs $5). So, in this example, wheat provides iron at a cheaper cost than the alternative: the child will choose to have wheat for their meals, and will have between 8.6 and 34.5 servings over the course of the day to meet their minimum of 10 mg and not exceed their maximum requirement of 40 mg of iron per day.

Of course, the child needs more than just iron, and so, with more and more nutrients to consider, the calculations get complex. That is why it is better to use the general guidelines and the chart attached to this chapter previously.

But, even if you were to build a linear equation to solve for the minimum cost based on current prices and the nutritional information from all known foods, this does not make the meal palatable: besides cost, flavor must be considered.

Dietary budgets

It does not take much in America for a pauper to eat like a Prince:

$1 per meal is the difference between the wealthiest Americans and the poorest Americans.

It is perfectly acceptable to spend cents (or sometimes even dollars) more per meal to get more preferable substitutes in meeting your RDI's. Spending a dollar more per day per person per meal with a family of four results in only $1,461 more spent per year. If you set a budget and then hold yourself to that budget, you will not spend more than you ought to and can still get the foods you enjoy best. If you set your budget to the "minimum" possible, you will not get the foods you enjoy. That said, the primary purpose of food is not for enjoyment, but for nutrition. Do not sacrifice nutrition for pleasure: if you do not enjoy the general guideline of "fruits and vegetables," and cannot find any fruit or vegetable you do enjoy (or, if there are no fruits and vegetables available), consider the balance of nutrients in your diet according to the tables presented earlier in this chapter. Can you go without fruits and vegetables? What dietary changes would you need to increase your fiber, minerals and vitamins that you miss with the fruits and vegetables?

For those who really detest fruits and vegetables, some options exist. Eat like a carnivore: if you can't eat like a horse, eat like a lion: a variety of very fresh raw organs provide similar nutrition to fruits and vegetables (be sure to eat the bones of the animal, if possible, as well for the marrow and the fiber). The Inuit of the Arctic live a largely carnivorous lifestyle, especially enjoying the fresh organs of the animals they kill, but deeply indulge in the seasonal berries, vegetables and other fruits of the Arctic spring, summer and autumn when possible. In this sense, they choose an omnivorous diet and eat like bears.

Just beware, humans are not very well able to digest animal protein, and doing so results in the production of uric acid and other poisons in the gut and blood that can result in disease of the various organs (especially the cardiovascular system) and reduced life expectancy. Those who use dogs on the farm for work are smart to feed them a vegetarian diet, and those who would work themselves like dogs should choose a vegetarian diet as well.

Teaching culinary skills to children

It is necessary to learn to cook and prepare meals: this is not an instinctual skill! While humans are capable of learning the skill on their own, it is better taught by a parent to a child.

Medical science teaches that the purpose of all life is to replicate itself. While animals can reproduce themselves physically through birth, whether from an egg or from a uterus, the process is not complete until the baby animal learns how to behave like its parents. The most basic purpose of a "mind" is for replication: the mind is a sexual organ, able to teach the adaptive behaviors unique to the species to the next generation (thereby "replicating" the previous generation). The mind allows a parent to teach and a child to learn.

Humans are very complex animals, and require their babies to learn many things. Baby humans learn how to read and write, how to undertake mathematics and scientific inquiry. But, just like all animals, baby humans must learn what and how to eat. Children are always ready to learn from their parents, and are no less ready to learn how to eat. The best way children learn is by example. If the parent eats well, the child will eat well, too.

And yet, example only goes so far. While each parent or teacher is most familiar with their child or children, this chapter is designed to provide inspiration in the education of a child with

specific ideas and suggestions on how to teach a child what to eat quicker than they would learn how to eat by example. The best advice is to not underestimate the ability of the child: if great things are expected of them, they will rise to the challenge; if little is expected of them, they will achieve little.

By the time a child is able to physically manipulate food, they are ready to learn how to cook and prepare their own food. The youngest child will begin this process by playing with the food on their plate. With careful supervision and training, a child can master all the arts of cookery as quickly as they learn how to speak, read and write, conduct mathematics and undertake scientific inquiry.

Children learn best by their food. Infants explore their world by their mouths first. A child who is rearranging the food on their plate can learn how to arrange food properly.

A child that helps out not only in the growing of their food but in the culinary preparation of the food they've grown eats better because such a child fulfills their purpose of helping out mom and dad while learning how to one day care for old mom, old dad and their own children. A child learns so much by helping out: not only in the basic skills of literacy, arithmetic, logic, reason and craft, but also in advanced skills of science and art!

Farming and Democracy

From the growing of food grows mighty Empires, from the making of bread is made honorable men and women. By teaching a child to nourish themselves physically, you teach them to nourish themselves mentally and spiritually and this basic self respect helps them learn how to care for others.

Talk with your child, spend the time with them to explain everything. Explain what you are doing, why you are doing it, think out loud to reveal to them how to think logically, how to express emotions before they develop into psychosis. Count with them, walk with them, stop and look at interesting things. Take a joy in life, and your child will too. Look to books for answers and your child will enjoy reading.

Whether your child is young or a grown adult, they never stop learning from mom and dad, and never stop relying on mom or dad to help them grow stronger. No matter how old mom and dad are, they are never too young to rely and lean upon their children for help in every day life: trust your child with important tasks and you will not be disappointed with the results. From the responsibility, your child will gain the discipline they require to make you (and themselves) proud. If you trust them enough to undertake with them a task you could not undertake alone, you will find a friend and helpmate; if you doubt their ability and believe them to be a burden you must care for, you will break under their growing weight as you carry them from place to place while they mature. Train them so that you can entrust them with your cares entirely, so that they may entrust to you the cares of their Republic: in a Republic youth grow strong working in the fields while their parents carry on their shoulders the affairs of State.

How many quarter cups are in a cup and a half of flour? How many servings are in a cup of sugar? How much iron is in a pound of oats, and why do you need iron? What is iron? From planning out a meal that meets the recommended daily intakes, you can quickly find yourself in geology, archeology, astronomy, anatomy, painting, colors...even medicine.

If you do not limit their line of questioning, you can uncover connections and truths that have remained elusive even to the most gifted of philosophers. If you direct the line of questioning,

you can prepare your child to undertake the work that is required of them by their Republic, their family and their friends when, one day, they are as old as you. How do you direct the line of questioning? Ask them questions of your own: "how would you apply this to that?" Encourage them to ask you what you do and why you do it! Not only will they likely see ways to improve your efficiency, but they will learn how to think critically. Involve the child with the most current learning of the day. If there is a debate in the Statehouse, ask them to apply the lessons learned while cooking to the debate; if you are facing problems in your own work and life, show them how to apply what is learned while cooking to the problem.

The lessons of a loaf of bread can extend very far, from the administration of taxes to choosing the best nail to fix a cabinet, from planning which crops to grow to how to treat the other human beings that you rely upon every day for electricity or oats. Use the kitchen and the garden as a classroom and you won't be disappointed in the lessons you teach.

Little Hands are Different from Big Hands, Big Hands are Different from Old Hands

Your child is probably smaller and physically weaker than you, they are probably less skilled in craft and know less. Yet this does not mean they are not up to any task: tasks help them grow, and they must learn how to thrive and grow stronger on challenges. That said, there are always small tasks that they can do easier, and these small tasks are important. A child may be too small to lift a jug of milk to pour it into a measuring cup, but this same child would have little problem cracking an egg. While undertaking this smaller task they can look at the egg and see how it would have grown into a chicken. They can examine the protein of the egg, and learn the chemistry that allows the egg to make pancakes fluffy. Maybe the child is crafty enough to flip a pancake, or to, at very least, begin learning how? So many lessons to learn!

In the garden, if the child is too weak to till the soil with a big shovel, invest in a small shovel for them. If they grow tired, have them take out a book and entertain the adults who are not tired by reading poetry, a favorite story, or even Herodotus's history. Perhaps the child can sing a song or play a musical instrument to make the work easier for the adults, until the child is well rested? Maybe the child can even make lunch for everyone?

As children get older, you will get older, too. One day, you will find that you are weaker than your child. One day, they will shovel while you read to them, or tell them stories from when you were young. Then, maybe, you will also have grandchildren: imagine the lessons you, the experienced elders, and the grandchildren can learn while helping out the strong adults?

Old people, young people and adult people all need to eat differently because they have different bodies and do different things. This lesson is repeated in the "classroom" of life that abounds in your garden (baby birds eat differently than adult birds, baby butterflies eat different than adult butterflies).

A Child's Garden

Give a child a piece of land – however small – and they will not disappoint you. Encourage them by showing how they can help the household by undertaking gardening. Give a child work worth doing and you will find them always at some worthwhile work. A small child can even undertake a new enterprise with great success. Maybe the garden is doing fine, but the family would like fresh eggs. A child, even a young child, can domesticate chickens or ducks and provide to

the family (and paying neighbors!) dozens of nutritious eggs per week. Maybe the child wants to grow a specific kind of crop you usually don't grow (oats or rhubarb, for example)? Maybe the child wants to take care of the family's trees and bushes? Or train the young work animals?

It is never too early for a child to prepare for their working life. Is there a neighborhood business that your child can help out at and learn from? In this way, a child can get the necessary jump-start on learning anything from mechanics to veterinary care, from engineering to salesmanship.

Teach the child that their skills are required by not only their family, but by neighbors and the community at large. Many of the wealthiest men and women in America remember with warm kindness their youth, when they first started and ran their own business. Teach them the arithmetic required for bookkeeping, the importance of paying tax, the importance of saving money in times of plenty for times of scarcity. Toys should be useful, play should help them grow. In other Republics, the children are grown strong by being expected to contribute to the household's wealth in some way even by the time they are five years old! Adults are kept strong by playing games and with toys even into their old age.

A child's garden is their classroom; a good classroom teaches lessons with or without a teacher. A child learns better in a good classroom with a teacher than without. The more time you spend with your child the more you can help them grow.

Just as young equines and bovines will learn their farmwork from their older and more experienced parents, so too do the young humans of your farm learn their work.

A child's kitchen

The work of cooking is not some burden to be shifted upon any one person, or passed from one person to another. Cooking is no punishment or chore. Cooking is a joy, a joy of feeding not only yourself, but those you love. Teach your child how to eat well, how to cook well, and give them the chance to care for you as you care for them. Love is best when reciprocated.

If the food the child cooks is bad, don't be afraid to say so: but say why it is bad so they may learn. There is no shame in falling when by falling we learn to run, there is no shame in making mistakes or falling short. It is a rare thing when we cannot do better by trying again: there is always a second chance. It is a good lesson for living well to learn how to err without shame, to never give up the hope of achieving better through another attempt. Never give up until the job is done good enough.

Yes, sometimes the dinner will be ruined and must be thrown out. This is a small expense for the learning of your child. If it is dinner time and the dinner must be thrown out, show the child how to cook a quick meal so that everyone can eat roughly on time: there are many delicious recipes that take less than 15 minutes to prepare! Some can even be served instantly!

Take responsibility for not having taught them well enough, and encourage them to ask for help, praise them when they achieve a triumph on their own. Teach them they can rely upon you – even as you want to rely upon them. It is best to learn a recipe together, and then have the child cook it under supervision, and then without supervision. Eventually, when the child becomes crafty enough, they will even be able to learn new recipes without your help, and come up with their own...and they can teach you!

Begin with the recipes that do not require cooking (such as salads), and then progress to more and more complicated cooking techniques.

Life is a picnic

Packing a lunch to go is an especially good skill to learn. Whether the child is picnicking at school, in the garden with mom and dad, or even during a day hike in the woods (or a longer camping trip), it is important that the child learns not only what they have to bring with them, but what is available. Why pack a salad when you're going to be eating in the lettuce patch, or in a field of dandelion? What foods require refrigeration, what foods will spoil after how long? How do you wash food that you harvest at the picnic site? What do other animals do to take food with them when they travel?

Life is a picnic, and what you pack with you while still at home and a child you must bring with you your whole life. Make sure that your child brings the physical and spiritual nourishment they will need their whole life long.

Selected bread recipes

While the *Joy of Cooking* or other cookbooks are essential supplementary reading, we have included several basic recipes to demonstrate basic bread-making skills. From such basic skills, the chef begins to learn how to do complex things: the skill of being able to make a salad dressing out of vinegar and spices to suit the day's desires of the palate transcends recipe writing, and demonstrates where basic culinary skill ends and experienced cookery begins. (This said, a basic vinegarette consists of ½ cup of rice vinegar, a tablespoon each of garlic, black pepper and onion powder, and salt and ceyanne to taste).

The genius of the dehydrated sliced zucchini chip, or the subtlety of the baked or French-fried potato, the simplicity of the roasted ear of corn or sweet yam requires significant training and, while bread is simple in its mathematical reliability, a stir-fry of noodles is not. Those who can train themselves on bread quickly learn the skills required to add sauce and cheese to the bread to make pizza, or how to produce a soup to dip the bread into.

This alone will be added here, and that is the best way to make a vegetable soup is to not add flour to it. Many beginning chefs make this mistake, and those who can avoid flour in their soup find that any combination of vegetables with just a little salt in the broth makes a most appetizing dinner – especially if some beans are prepared in the broth itself with the vegetables.

Cornbread

Cornbread is an excellent staple for the diet, and is good accompaniment for any meal. While any flour can be used, whole grain flour provides the best nutrition. White whole wheat flour is the sweetest variety of whole grain flours, and has a richer flavor than non-whole grain flour.

This cornbread (as with most cornbreads) is a "quick bread," meaning it has no yeast and instead relies on chemicals (in this recipe, baking powder) to rise. These "artificial leaveners" require no kneading or extra rising time, so the bread really is ready much quicker than more traditional yeast breads.

Makes 9 pieces

- 1 ¼ c. white whole wheat flour
- ¾ c. corn meal
- ¼ c. sugar
- 2 Tbsp baking powder
- 1 c. milk
- ¼ c. corn oil
- 1 egg

Preheat the oven to 400F.

Combine all ingredients, mixing very well. For the smoothest batter, mix following the addition of each ingredient, in the order listed.

Oil an 8x8 pan, pour batter in and smooth it out so it is about evenly thick throughout. Bake for 20-25 minutes, until golden and just starting to lightly brown on top, and a toothpick inserted in the middle comes out clean.

Serve warm with honey or herbed honey butter.

Cornmeal Pancakes

These pancakes are not much more than pan-cornbread, but the convenience of not needing an oven to make your favorite cornbread is not to be underestimated. Use the recipe above, but do not use any eggs. Add ½ to 1 cup more milk (1.5 to 2 cups total, until it's runny). Add butter to the pan to avoid sticking.

Pour the batter on a hot pan and flip when it starts to bubble. You'll get the hang of flipping these flapjacks with a very little bit of practice. Try to get them golden brown!

Basic Whole Wheat Bread

This bread recipe is adapted from a standard French bread (pain ordinaire) recipe. Unlike French whole wheat bread (pain complet), this bread uses no milk. This bread is perhaps the most simple of yeast breads, and a good one to practice on if you are just starting to practice using yeast and learning to knead by hand! The flour should be all whole wheat, but you can use white or standard red whole wheat flour. Try using some of both! We suggest mixing ¾ white whole wheat with ¼ red whole wheat for the best flavor. The loaf is wonderful fresh with honey butter, or dipped in golden olive oil. It also makes good sandwiches and toast!

Makes 2 regular loaves or 1 large loaf

- 2 c. warm water
- 1 Tbsp sugar
- 1 ½ Tbsp (2 packages) yeast
- 1 Tbsp salt
- 5-6 c. whole wheat flour (white or red)
- Golden olive oil and cornmeal, to keep the bread from sticking to the pans

Warm the water to a temperature that is "like bathwater," meaning that it is warm to the touch but not so hot as to be uncomfortable to touch. Combine in a mixing bowl the water, sugar and yeast. Mix briefly, until the yeast is mostly wet and submerged. Let sit for about 10 minutes. By the end of this time, the mixture should become foamy. If it hasn't, start over! The foam means the yeast has activated, which is absolutely necessary. If your yeast continues to not activate, check your yeast's expiration date, and also try different temperatures for the water.

When your yeast is activated, add the salt and two cups of flour. Mix well, so the mixture is creamy. Add 3 cups of flour, and begin kneading. You can do this in the mixing bowl, if large enough, or on a floured surface. To knead, press the dough firmly down and away from you. Pick in up and turn it partially over, and press again. Keep rotating and pressing until the dough becomes well mixed and slightly elastic in texture. Add more flour (up to one cup) and knead it in, until the dough is no longer sticky.

Prepare one or two bread pans: coat the inside thoroughly with golden olive oil, and dust the bottom with cornmeal (to prevent the bottom from burning). If making two loaves, separate the dough into two evenly sized balls, lightly coat each in golden olive oil and place each in a bread pan. Spread and shape the loaf into a rectangle to fill the bottom of the pan. If making one large loaf, you will not be able to let it rise in the pan, because it will get too large. In this case, lightly coat the dough in oil and place it in a clean bowl that will allow it enough room to double in size. Cover the bread pans or bowl with plastic wrap or a clean towel. Let the bread rise for 1 ½ hours (until about double in size).

Your bread is now ready to bake. If making one large loaf, quickly and gently transfer the dough to the bread pan, so as to deflate it as little as possible. Place the bread pan(s) into a cold oven. Turn the temperature to 425F. Bake for 30 to 35 minutes. There are several ways to check if it is done: the top should be beginning to brown, the sides of the loaf should pull away from the pan, and if you flip the loaf out of its pan and top the bottom, it should sound somewhat hollow.

Let cool completely, and then store un-refrigerated in a sealed bag.

Biscuits

Biscuits are a delicious "quick bread," and faster to make than many other quick breads! They are great eaten with jelly, honey, or as small sandwiches.

Makes 8 biscuits

- 2 ½ c. white whole wheat flour
- 1 ½ Tbsp baking powder
- ½ tsp salt
- 1 Tbsp sugar
- ½ c. (1 stick) butter
- 1 c. milk
- Cornmeal, for the pan.

Preheat the oven to 425F.

Mix all the dry ingredients (flour, baking powder, salt and sugar). Melt the butter. Add butter and milk to the mix. Combine well.

Prepare a baking sheet: line with aluminum foil or oil it. Dust liberally with corn meal to prevent the bottoms of the biscuits from burning.

Form the dough into eight balls, each about 2-3 inches across. Press the balls on the baking sheet to make into a disk about 1 inch tall.

Bake for 10 to 12 minutes, or until they begin to turn golden brown on top.

Cream of Wheat

While you can buy the cream of wheat in the box labeled "cream of wheat," ordinary flour works well, too. Some people prefer coarse flour for their cream of wheat (Aaron does), others prefer fine-ground flour for their cream of wheat (Mary does).

For an interesting change, substitute ¼ of the wheat for rye or corn flour!

Serves 2

- 2 ½ c. milk (or 2 ¼ c. water)
- 3 Tbsp wheat flour

Heat just under a boil, stirring frequently, until it achieves the desired consistency.

4-alarm chili

Though not bread, this simple recipe also provides some basic training in culinary skills while allowing the chef to begin to learn the subtlety of spicing. There is no precise recipe: the chef must be relied upon to understand the demands of the palate!

Prepare your favorite beans (we like pintos for chili) by combining ½ cup beans with just over 2 cups water. Into the beans add onion (powder or finely chopped), garlic, cumin and cilantro. Do not ever add salt to beans or rice as they cook as it will make them rock hard. Add salt afterwards. Just before the beans are done, add to them finely chopped chili peppers: jalapenos, anaheims, ceyanne and chipotle (which are roasted red jalapenos). Each pepper has its own flavor, and should be treated as a unique spice! The secret ingredients: at the same time, add in chopped tomatoes or tomato paste (we recommend ½ to 1 cup of tomato paste to each cup of beans) and a tablespoon or two of corn oil.

Black Bean Open-Face Burritos

Was the 4-alarm chili overwhelming? Here is a slightly more structured recipe to fine-tune your skills.

Don't know what to have for dinner? Not hungry? Try this delicious, mouth-watering, satisfying dish: no matter how much you make, you'll be sure to clean your plate. This recipe is a hearty and almost nutritionally balanced meal all on its own, and it is quick and easy to prepare!

The options for toppings are seemingly endless! Try different cheeses: regular cheddar works well enough, but feta or chevre (goat cheese) add a creamy and unique flavor. The rice, too, can be

altered to suite your preferences: try an aromatic rice such as jasmine or basmati, or add a pinch of saffron while cooking. Even the choice of oil for frying is flexible: corn or olive are both recommended, and yield slightly different flavors. Choose from just one of the toppings, a few at a time, all at once...or none at all!

This recipe works wonderfully as a vegan meal, with no cheese at all (Mary and Aaron usually have it this way).

If you prefer a lower-oil meal, you can still make some of the fried toppings! Just blot the finished fried toppings with paper towels before serving. This will remove the excess oil.

We suggest eating the burritos "open-face," or unrolled and assembled like a pizza, spreading each layer across the tortilla, because few tortillas made without poisonous gums are strong enough to hold together with this filling. If you cannot get any tortillas made without gum and do not make your own, pita bread will suffice. No pita bread either? No problem. Just eat out of a bowl or off the plate.

You (or, more likely your guests) may notice the lack of salt in this traditionally salty dish. We prefer it without salt, but understand that some people are so used to a salty diet that this burrito tastes bland without it.

Serves 2

The Basics

- 2 c. cooked rice
- 2 c. fresh or 1 can (15 oz) no salt added black beans
- 10- or 12- inch tortillas, or 4 8- inch tortillas (corn or flour)

Toppings to Choose From

- Fried onions and tomatoes:
 - 1 Tbsp golden extra virgin olive oil or corn oil
 - 1 c. chopped onion, scallions, or leeks
 - 2 garlic cloves, minced, or 1 tsp garlic powder
 - ½ tsp ground cumin seeds
 - 2 large "beefsteak" tomatoes or 4 regular tomatoes
- Fried potatoes:
 - 1 large potato
 - 1 Tbsp golden extra virgin olive oil or corn oil
 - 1 c. chopped onion, scallions, or leeks (optional)
- 1 bell pepper
- 1 c. chopped tomatoes (or whole cherry or grape tomatoes)
- ¼ c. shredded or crumbled cheese of your choice
- Salsa
- Hot sauce
- Sour cream
- NOTHING AT ALL!

To make the basics: cook the rice according to the package directions. Separately heat the beans over low heat to warm them.

To make the fried onions and tomatoes: Chop the tomatoes into approximately ¾ inch chunks, and slice the onion. Heat the oil in a skillet. Add the onions and garlic. Cook until they are almost done. Add the cumin, stir once, then add the tomatoes. Cook until the tomatoes start to

soften and fall apart. Stir according to your preference: stirring frequently will turn the tomatoes into almost a paste; stirring infrequently will result in a chunkier sauce. Remove from heat if done before everything else is ready, or keep warm over low heat.

To make the fried potatoes: slice the potato into pieces no more than ¼ inch thick. If using onions, slice them also. Heat the oil in a skillet. Add the potatoes and onions. Cook until the potatoes are browning and cooked to taste.

To prepare the bell pepper: Cut the bell pepper into strips after removing the seeds. You can use the bell pepper fresh, cook it with the fried tomatoes and onions or the fried potatoes, or cook it briefly on its own in a little bit of oil.

To prepare the tomatoes: If using cherry or grape tomatoes, clean them and leave them whole. If using any larger tomatoes, slice them to bite size pieces. You can use these fresh, or warm them with the black beans.

When the rice, beans, and topping(s) are all ready, assemble them on the tortillas.

Back to Basics Chocolate Chip Cookies

Cookies present a calorie dense food to support farm operations and for those of us who work exceedingly hard during the day, they can be a life saver in the afternoon when there is too much work to quit early for dinner. And, these, if made without the chocolate, are a great treat for the work animals too.

These cookies are actually fairly nutritious already, but if desired, fortification with minerals and vitamins is easy too. Whole grains and dairy: they're like tiny, well cooked pancakes!

After much research into the variations of chocolate chip cookie making, we decided the best recipe was the following creation, which only uses those ingredients that are most commonly found in chocolate chip cookies, and no funny business!

To make them soft or make them crunchy, simply vary the baking time. You can also easily change what you use with or in place of chocolate chips: try breaking up candy bars for chocolate chunks or adding some nuts. We especially enjoy these with chunks from a bittersweet chocolate bar.

These cookies sustain our farm operations almost by themselves. We rely upon them when we start to feel fatigued mid-afternoon and need a quick rush of energy, we rely on them to keep our Landlords very satisfied with us (whose eyes light up upon seeing a plate full of them), we rely upon them when the workers and animals start to get tired, and rely upon them to help us seal the deal with other farmers we are cooperating with.

Few phrases get better response at our farm than "who wants a cookie?"

Luckily, this recipe doubles well, is quick to cook and can be almost mass produced in a home kitchen.

Makes 1½ to 2 dozen cookies

- 1 c. white whole wheat flour
- 1 ¼ c. rolled oats
- 1 tsp baking powder
- ¼ c. sugar
- ½ c. brown sugar

- ½ c. (1 stick) butter
- 1 tsp vanilla
- 1 egg
- ½-1 c. chocolate pieces

Preheat the oven to 375F.

Mix the flour, oats and baking powder. Separately, melt the butter. In a separate bowl, mix the sugar, brown sugar, melted butter, vanilla, and egg.

Combine the flour mix with the sugar mix. Stir well, until your cookie dough is fairly homogenous. Stir in the chocolate pieces.

Line a cookie sheet with aluminum foil. Make dough balls and slightly flatten them or drop the dough directly on the sheet, so each cookie is about 1 to 1 ½ inches across. Leave at least an inch between cookies.

Bake for 8 minutes to get soft cookies, 15 minutes to get crunchy cookies, or anywhere in between.

If the cookies are not eaten right away, you can refrigerate them and reheat them briefly in a preheated oven for about one minute, or in the microwave for a brief time (just until they are warm).

We recommend lock-and-key to protect them from scavengers.

Drop and Pop-Pop Cookies

Drop on the pan, pop in the oven, pop into mouth. These cookies are about as easy as they get. Try dividing your batch into thirds and try some with the coffee, some spiced and some with the chocolate!

These cookies take very little time to prepare, and even less time to eat.

Makes 2 dozen cookies

- ½ c. (1 stick) butter
- ¾ c. sugar
- ½ tsp vanilla
- 1 egg
- 1 ½ c. white whole wheat flour
- ¾ tsp. baking powder
- ½ c. milk
- 4 tbsp Ovaltine
- 3 tsp coffee

OR

3 tsp ginger, 1 tsp cinnamon, 1 tsp cardamom, 1 tsp nutmeg and 1 ½ tsp allspice

OR

dark chocolate chunks

Preheat the oven to 375 degrees. In a large mixing bowl, combine all ingredients except the butter. Set aside.

Soften the butter by heating on the stove or in the microwave briefly, until it is soft enough to be easily smashed with a fork, and is just about to become liquid. Remove from heat and stir until creamy.

Combine butter and the other ingredients (if trying all the variations – coffee, spices, and chocolate – combine all the ingredients through Ovaltine, then divide the dough and add the appropriately reduced amount of variation ingredients).

Drop with a spoon onto an unoiled cookie sheet (line with foil for easy cleanup, if desired) about two inches apart. Pop into the oven and bake 10-14 minutes, or until just starting to brown. Then, carefully, pop into your mouth.

Almond bread

This recipe was invented by Aaron's Grandma Ruth, and was great. Aaron improved it and, though Aaron's Grandma and father might disagree, everyone else seems satisfied that it is now even more delicious. This "bread" is actually more like a cookie, and is, despite the 3 cups of whole grains and 8 ounces of nuts, not an everyday food.

Chopping the almonds finely is a skill that is easy to learn. One day, Aaron's Grandma asked Aaron's Grandpa to chop some almonds for this bread. Aaron's Grandpa asked if Aaron wanted to learn how to chop almonds? Of course.

Grandpa took a knife and a plastic bag and said he was going to enjoy the nice spring air. With Aaron following, Grandpa stopped off at the garage tool box for a "culinary hammer." Sitting on the driveway where Grandma couldn't see, Grandpa quickly "chopped" the almonds with the culinary hammer in just a minute. Aaron was ready to go back inside. "Not quite yet," said Grandpa. After enjoying the birds singing and the cool breeze for more than a half hour, Grandpa and Aaron wandered back to the kitchen. "You chop them so fine!" Grandma was pleased at Grandpa's hard work.

We recommend placing the almonds in a clean ziplock or canvas bag (an easy to wash reusable canvas bag can be made from a pant leg from an old pair of jeans: sew up one end, and prepare a draw-string for the other). Then, place the bag on the kitchen floor (or the driveway out of view from the kitchen's chef), whack at the nuts vigorously with your culinary hammer until the nuts are "finely chopped."

Another good way to chop nuts is placing them in the blender...but whacking nuts vigorously with a hammer is more fun and just as fast.

The only more fun way to chop nuts than with a culinary hammer is with a nutcracker...not one of the simple metal kinds that you squeeze between your fingers and palm, but the straight-from-Tchaikovsky Russian-doll type that eats the nuts as fast as you can feed them.

Makes 3 loaves (about 3 dozen pieces)

- 3 c. white whole wheat flour
- 1 c. sugar
- 2 tsp baking powder
- 8 oz sliced almonds
- 1/8 c. of water
- 1/4 c. (½ stick) butter, melted

- 4 eggs
- 1 ½ Tbsp vanilla extract
- Cinnamon and sugar topping (optional)

Preheat oven to 350F.

Mix all ingredients together, except cinnamon and sugar topping, and kneed the dough. Cut and mold the dough into three long, thin loaves (about 12x3), and arrange on a non-oiled cookie sheet. Sprinkle cinnamon and sugar on top, if desired, before baking. Bake for 20 minutes. Immediately after removing from oven, slice the almond bread into small pieces for individual servings: if the almond bread cools, it will be very difficult to cut with anything less than a "culinary hack saw."

Lemon Candy

Though not a bread, this candy is very easy to make, and the perfect solution for when you have some fresh lemon juice left over from another recipe. It also is useful to have on hand for making a quick glass of lemonade without needing to make a whole pitcher.

Makes about 1 cup, if using a small lemon

- Juice from one lemon, or however much you have on hand
- Sugar

Squeeze the juice into a bowl. Add sugar (without stirring), until the added sugar no longer absorbs the juice. Stir briefly, and add sugar again until no more juice is absorbed. Add a little more sugar to form a thin (1/8 inch) layer of plain sugar over the candy.

Eat right away or store (covered) in the refrigerator for several days.

To make lemonade from the candy, combine 2-3 Tbsp of candy per 1 c. water, or to taste.

Basic Pancakes (modified from the Joy of Cooking)

These are your basic pancakes. Pancakes are excellent food for hardworking men, women, children and their overly pampered and loved oxen, horses and other animals. Add some fruit or nut toppings, but reduce the water somewhat if you are using canned fruit to maintain the consistency of the batter.

Combine in a large bowl

1 ½ c. white whole wheat flour
1 Tbsp. sugar
1 ½ tsp. baking powder
½ tsp. salt
1 ½ c. milk
3 Tbsp. butter

2 large eggs
½ tsp vanilla or almond extract (optional)

Whisk together, pour the batter on a hot pan and flip when it starts to bubble. You'll get the hang of flipping these flapjacks with a very little bit of practice. Try to get them golden brown!

CHAPTER TWENTY-EIGHT: OF ORCHARD AND FOREST MANAGEMENT

Orchard and forest management builds on theory, tools and practices discussed previously: trees are just large plants. Discussion on why not to prune, discussion on aisles in forests, why selling firewood makes sense in orchard management even though the firewood costs as much to harvest as it does to produce, why saplings benefit from tillage more than established trees, polycultural forests and orchards, and intercropping trees with annuals

This chapter on orchard and forest management is necessarily short, as it builds upon the concepts previously introduced in this book. What are trees except very large plants? And the possibility of integrating annual or other crop production between the trees of a forest or orchard is little different than the polycultures of a normal bed.

That ginseng, mushrooms, coffee and other shade-loving crops can be grown with success under the sheltering bows of trees requires little discussion, but simply an application of the farmer's understanding of their climate and their desire to earn the most profit from their land. The use of polycultures in tree planting (and the employment of wild reservations with trees that may or may not produce things of value), again, is no different from the agriculture of smaller plants.

Proper tree spacing does not break the rule, either. Plant them so that when they are mature, they just barely touch within their rows, and so that you could have an entire "bed" of trees between beds as your aisle.

Tillage helps trees most when they are youngest and their roots are closest to the surface of the soil.

A note or two should be made on trimming trees. If you trim trees, you make it more convenient for the farmer to harvest and work among the trees. But you also reduce the efficiency and health of the tree. Every cut invites disease, and shaping the tree reduces its strength against the weather that helped shape it. Every wind burst, every breeze, every snowflake or raindrop carefully, gradually shapes your trees better than your pruning saw or clippers and trees that are not shaped by human hands are necessarily shaped as the weather wants: each snowstorm helps prepare the tree for the next one.

Some orchardists remove flowers to help the tree put more energy into its remaining fruits. This has some obvious benefits that are obvious (bigger fruit) and some costs (less fruit) that the farmer ought to weigh. Do not fear small fruits – they are excellent for juicing, winemaking, cider, flavored vinegar and other useful products.

Plant lumber trees close together and the trees will grow tall and straight. After initially planting sun-loving trees (like lodgepole pines or cottonwood), harvest irregularly in the forest and replace trees with shade-loving trees. Begin a forest irregularly also so that you may stagger the harvest later: good records and observation will help you identify where trees are ready and when. Forests that are clear cut are less healthy because the animals, fungi and microorganisms that the

trees rely upon do not adjust well to a clear cut. Try not to clear more than 20% of the forest every 5 to 10 years. However, some circumstances may require more clearing.

The reason why lumber trees grow better in shade is because the lack of light stimulates them to grow taller to reach above the canopy: this phenomenon is seen in reverse when carrots are planted in density, and the roots stretch deep and straight to find their food and avoid their neighbors. Thus, in many lumber forests, the farmer will retain very small aisles – only big enough for their tractor or animals to work in (after all, you'll need to harvest those trees and drag them out of the forest and aisles are very handy for that).

Besides lumber for building construction, lumber can also be used to make quality mulches, firewood, tools, boats, pencils, flagpoles, toys, tent posts, etc. If you plan on direct marketing, you may want to invest in a mill, or hire a craftsman to make your lumber into something even more valuable (lumber is valuable enough, though!).

Some trees are good for both orchards and lumber.

Very few trees are good for sapping (sugar production), and while any maple or birch will produce quality sugar, some breeds are better than others and the sugar maple exceeds all others.

Some dead trees should be left in the forest for the use of wildlife. Dead trees are excellent habitat for those animals you will depend upon to keep your living trees safe and sound. Woodpeckers, especially, love deadwood to live in.

If you begin your forest with a wooded lot, to clear land for your planting, harvest all those trees that are in the aisles first, then harvest in those positions on the beds where you intend on planting your first trees. This will allow your new saplings to grow up in shade. Even though the wild lumber you harvest will be of lower quality than the trees you are raising, the health of your forest and the new saplings will be maintained better by allowing it to transition gradually instead of at once through a clear-cut and fresh start.

Once trees are mature, some farmers earn extra money by stocking their forest with game and charge hunters that want to undertake hunting in the forest. If you mind the occasional bullet in your wood, allow only bows and arrows, and provide a "guide" to monitor that all arrows are extracted from wood it might strike.

Firewood is the most basic use of lumber, it represents the minimum a farmer can earn on their lumber as it only just barely covers the cost of production. But is an easy way to clear orchard trees at no cost, if you do not have the craftsmanship or the milling capacity to manufacture a higher quality product. Thus, we advise only to raise lumber as a secondary product: make the trees work by producing nuts, fruit or sugar, then clear them at no cost to yourself by making them into lumber.

Lumber fuel can be processed into firewood logs (chopped into parts small enough to fit in a standard fireplace), chipped into stove fuel, or pressed into pellets for high-end fuels designed for mechanical wood burning stoves. Such a press is expensive, but often worth the cost. Getting a chipper and a wood chip burning stove to heat farm buildings, though, is often worth the investment.

For firewood, quick-growing softwood fast burning woods (like poplars and cottonwoods) or slow-growing hardwood slow burning woods (like apple) each present a decent profit. Hard woods are more valuable than softwoods, and the higher the oil content of the wood, the higher the value. Pine and other good-smelling woods are valuable; mesquite and other flavored woods present a high-value firewood designed for culinary uses in smoking, cooking and preservation of food.

A cord of wood (128 cubic feet, 4 foot x 4 foot x 8 foot) in 2005 in Colorado was worth about $200, though cheap cords were priced at $100 and valuable cords were priced at $500. Many (we

hate to say most) dealers regularly take advantage of their customers who are unfamiliar with how big a cord is, and sell a 1/3 or 1/2 cord for full price. More dealers sell a 3/4 cord for full price.

The estimation of yield is an act of geometry that usually underestimates yield. The farmer examines the average internal area of the tree's trunk multiplies it by the tree's height to find the volume of the tree, and discounts all lateral branches.

Estimating the internal area of the trunk is easy enough: the Area is equal to Pi multiplied by the radius of the tree squared.

$$A = Pi \times Radius^2$$

Pi is an mathematical constant equal to roughly 3.14. A circle with a diameter of 1 will have a circumference of Pi, but any circle's circumference divided by the diameter will produce a ratio of Pi.

The radius is found by measuring the circumference of the tree. This can be done by tying a string around the tree and conveniently measuring the distance on the string (instead shifting a measuring stick around the tree).

$$Radius = the\ Circumference / (2 \times Pi)$$

The height of the tree is found either by measuring it directly, or by a common estimation method that is much simpler and quick than the complex mathematics required for an exact measurement. Since the estimate is going to be "rough" anyway, most tree farmers will use this approximate.

A stick equal to the distance from your fist to your shoulder should be made. Walk away from the tree's trunk until, when looking at the stick held vertical up with one eye closed, obscures the tree from base to top (or to whatever height you wish to measure to).

The distance you have walked away from the trunk is (about) equal to the height you are seeking to measure. Thus, the volume of the tree's trunk is estimated:

$$Volume = \{Pi \times [Circumference / (2 \times Pi)]\} \times Height\ of\ the\ Tree$$

The measured radius at the top of the tree and the bottom of the tree can be averaged. Most farmers do not measure the very top of the tree, but some point in the middle where it is wider to better approximate the total volume of the tree.

The measurement of volume is then converted to cords: there are 128 cubic feet in a cord of wood and 221,184 cubic inches in a cord of wood.

A more complicated but more accurate method is to understand that a right triangle is formed between you, the base of the tree and the mysterious height of the tree. Because the

$$Base^2 + Height^2 = Hypotenuse^2 \quad therefore, \quad Hypotenuse^2 - Base^2 = Height^2$$

and

$$Height = the\ Square\ Root\ of\ (Hypotenuse - Base).$$

But you will need the hypotenuse to learn how tall the tree is...to solve for the hypotenuse requires solving for the relationship between the distance between your shoulder and hand (X) and the distance between your hand and the top of the stick (conveniently by plan also X)

X = square root of (Hypotenuse – Base)
so
Multiply the hypotenuse by the difference between your arm's length and the length between you and the tree.

We will undertake an example. A cottonwood is to be measured. According to the City of Cheyenne (http://www.cheyennecity.org/ DocumentView.aspx?DID=1150), a mature cottonwood will grow to between 60 and 100 feet tall, with a canopy spread of the same measurement. Plains cottonwoods are about 20 feet shorter and 20 feet less broad. The diameter will be 5 to 6 feet. Significant tree roots will extend 1.50 times larger than the canopy. They estimate that the peak quality of wood will be present before 70 years of age, but that the trees will live to be about 100 years old. These are big trees, and though their firewood is esteemed to be of lower quality, we enjoy a cottonwood fire greatly. Their wood is also considered lower quality for construction, but is considered of high quality for ornamental work because of its beautiful white color.

The farmer decides to harvest the wood from a tree that has only achieved half its potential, believing that the wood will be of high quality. Cottonwoods grow about 5 feet per year under good conditions, and this cottonwood is 10 years old, though the farmer transplanted them at 3 years of age and so each cottonwood reflects 10 years of work.

They set out with a stick measuring the length of their arm from their shoulder to their hand, walking from the base of the tree until the stick obscures the tree from bottom to top. A quick measurement of the distance finds the tree to be 50 feet tall. The circumference at the base is found to be two feet, and at the top to be 6 inches: an average circumference of 1.25 feet.

Thus the farmer finds that the tree is worth...

Volume = {Pi x [Circumference / (2 x Pi)]} x Height of the Tree
Volume = {3.14 x [1.25 feet / (6.28)]} x 50 feet = 31.25 cubic feet
31.25 cubic feet / 128 cubic feet = 0.24 cords
1 cord = $200, $200 x 0.24 cords = $48

This is, of course, not counting lateral branches, which we estimate to add 25% to the total, bringing the value to $60.

While trees might be left to grow bigger or smaller, we'll use the average value of this random tree to estimate the value of raising similar lumber across an acre.

If the farmer spaces cottonwoods trees 40 feet apart within a 40 foot wide bed, and keeps a 6 foot wide aisle, there are about 4.54 beds per square acre, each filled with 5.21 trees, a total of 23.65 trees per acre. With an estimated value of $48 per cottonwood, the farmer earns $1,135.36 per acre after 10 year's work (about $114 per acre per year).

The work is minimal, tillage 4 times per year for the first 3 years. At 2 miles per hour, and at $8 per hour, each 40 feet costs $0.03, a total tillage expense of $0.03 x 4 tillings per year x 3 years = $0.36. The trees needed no water, no labor. Harvesting and cutting into firewood costs the owner 6 hours work (3 laborers working 2 hours each), at $8 per hour is $48. Total costs equal $48.36 per tree, plus any fixed costs associated with the land. Per acre, this amounts just about to the value of the firewood! It is a clear loss when the cost of the land is accounted for.

Unless the farmer markets the trees for a higher price, advertising their excellent qualities.

Those undertaking the harvest are not profit-oriented, their goal is to clear trees and pay for variable costs. Using old orchard trees as firewood covers the cost of clearing them out, and this

satisfies many farmers. Clearing forested land to make room for valuable crops satisfies others. The harvesters earn $48 per tree for their labor, but when the harvesters also own the tree and the land that is required underneath it, they are rewarded by the newly available soil better than the wages for wood.

Whether using wood for firewood or for other purposes, cure the wood by drying it in a warm, dry place. A barn with many windows (like a greenhouse) and good ventilation – or at least good ventilation – answers this need ideally.

Older trees are not as benefited by tillage as younger trees are, as the older trees have their roots generally so much lower than the plow can reach. They do not even rob the crops they stand near, whose roots are shallow compared to theirs! However, younger trees that are well cared for grow quicker and stronger and healthier.

Because young trees require so little space, they are often raised in a nursery and then transplanted to their final location on the field.

Trees are started from seed or cutting, and are gradually transplanted from sheltered location to more and more natural location. Some farmers begin their trees in a greenhouse with potting soil or compost as a medium.

John Chapman, the greatest American to have ever lived (as proclaimed by his Congress), made a fortune in saplings. He would receive free seeds at cider mills and plant them in the shelter of larger trees. Hoeing them and mulching them, he cared for them until they grew old enough to sell (usually a few years). He had nurseries along the paths of settlement in the Old Northwest of the United States and, as trees matured, he could sell them to settlers headed west. Because he had no costs but his own labor (his land was free, as well), he earned pure profit from his work, and could sell the valuable trees for a price that the poorest Americans could afford.

John "Appleseed" Chapman's life was a remarkable one. He easily communicated and worked with wild animals, which were known to even fetch firewood and food at night for him. He was befriended, defended, housed and fed by raccoons, wolves, eagles, bears and countless other creatures. He was befriended and defended by many Native American tribes and, during those terrible times of war, could walk into the middle of a raging battlefield and command peace from both parties. In such battles, he was sometimes shot at, but the bibles he carried with him could stop even several bullets from touching him. He never carried a weapon, never wore shoes, never ate meat, dressed in rags, and was otherwise a devout Christian. He gave away free bibles wherever he went; he taught Americans and Natives agriculture. He could walk into towns ruined by lawlessness and whiskey and in a day inspire the law and order of democratic self-government. To save a wolf from being skinned alive, he wagered a fortune against the wolf in a game of chopping trees: a field was divided in two and he was to cut one side, the entire town the other. Whoever cut the most won. Chapman cut as many trees in a day as the entire town could, and won the wager when a bolt of lightning from a clear sky cut down a final tree on his side of the field. It is said, by witnesses, that when Chapman died, his soul rose to heaven on a rainbow, escorted by the Angels of God: he died from an infected wound he received when chasing a friend's escaped cow through a blizzard. But for the many witnesses to his life's adventures, it would seem an extraordinary work of fiction, but he was a real human being and all he did was miraculous.

But of more relevance to this work, saplings are another way to earn money from trees: if the farmer ever has too many, saplings can be sold for much profit: 3 years of tillage and watering the seeds can yield $10 to $50 per plant, depending on the kind of tree: almost all of it clear profit.

When digging saplings, dig wide so that the roots are not damaged much. Bind the soil in a plastic bag, or keep them moist with wet cloth until transplanted into a transporting pot, or directly

into the ground. If in a wet climate, mound the soil close to the trunk so water is inclined to wash away from the roots; if in a dry climate, ring the roots with soil so the water sinks down around the trunk in a basin.

When transplanting saplings, dig a hole deep enough to submerge the crown at least 4 inches under the soil. Dig a wide hole, so the roots can be spread out into the ground.

Notes on lodgepole pines and forestry by Enos Mills

Enos Mills is quite verbose on the lodgepole pine in his *Wildlife on the Rockies* (1909), which should be read by anyone attempting agriculture – and especially those undertaking lumber production. Every animal, every plant, every fungus, every microorganism and person in the entire forest is important to the tree. Mills notes the natural density of trees (so the farmer can emulate nature), dangers of wood being spoiled by enveloping pinecones, and the general nature of the tree itself. In other books and in other chapters, he discusses how in the shade of the lodgepole other trees grow up, and in this way the terrific cycle of fire that characterizes lodgepoles is stopped.

Eastern forests are different than western ones, and wherever you raise your trees, you must heed nature as closely as Mills. Here is an excerpt from his book *Wildlife on the Rockies*.

The lodge-pole readily adapts itself to the most diverse soil and conditions, but it thrives best where there is considerable moisture. The roots accommodate themselves to shallow soil, and thrive in it.

This tree begins to bear fruit at an early age, sometimes when only eight years old, and usually produces large quantities of cones annually. The cones sometimes open and liberate the seeds as soon as they are ripe, but commonly they remain on the tree for years, with their seeds carefully sealed and protected beneath the scales. So far as I have observed, the trees on the driest soil cling longest to their seeds. For an old lodgepole to have on its limbs twenty crops of unopened cones is not uncommon. Neither is it uncommon to see an extensive lodge-pole forest each tree of which has upon it several hundred, and many of the trees a few thousand, cones, and in each cone a few mature seeds. Most of these seeds will never have a chance to make a start in life except they be liberated by fire. In fact, most lodge-pole seeds are liberated by fire. The reproduction of this pine is so interwoven with the effects of the forest fires that one may safely say that most of the lodge-pole forests and the increasing lodge-pole areas are the result of forest fires.

Every lodge-pole forest is a fire-trap. The thin, scaly, pitchy bark and the live resiny needles on the tree, as well as those on the ground, are very inflammable, and fires probably sweep a lodgepole forest more frequently than any other in America. When this forest is in a sapling stage, it is very likely to be burned to ashes. If, however, the trees are beyond the sapling stage, the fire probably will consume the needles, burn some of the bark away, and leave the tree, together with its numerous seed-filled cones, unconsumed. As a rule, the fire so heats the cones that most of them open and release their seeds a few hours, or a few days, after the fire. If the area burned over is a large one, the fire loosens the clasp of the cone-scales and millions of lodge-pole seeds are released to be sown by the great eternal seed-sower, the wind. These seeds are thickly scattered, and as they germinate readily in the mineral soil, enormous numbers of them sprout and begin to struggle for existence. I once counted 84,322 young trees on an acre.

The trees often stand as thick as wheat in a field and exclude all other species. Their growth is slow and mostly upright. They early become delicate miniature poles, and often, at the age of

twenty-five or thirty years, good fishing-poles. In their crowded condition, the competition is deadly. Hundreds annually perish, but this tree clings tenaciously to life, and starving it to death is not easy. In the summer of 1895 I counted 24,271 thirty-year-old lodge-poles upon an acre. Ten years later, 19,040 of these were alive. It is possible that eighty thousand, or even one hundred thousand, seedlings started upon this acre. Sometimes more than half a century is required for the making of good poles.

On the Grand River in Colorado I once measured a number of poles that averaged two inches in diameter at the ground and one and one half inches fifteen feet above it. These poles averaged forty feet high and were sixty-seven years of age. Others of my notes read: 9728 trees upon an acre. They were one hundred and three years of age, two to six inches in diameter, four and a half feet from the ground, and from thirty to sixty feet high, at an altitude of 8700 feet. Soil and moisture conditions were excellent. On another acre there were 4126 trees one hundred and fifty-four years old, together with eleven young Engelmann spruces and one Pinus flexilis and eight Douglas firs. The accumulation of duff, mostly needles, averaged eight inches deep, and, with the exception of one bunch of kinnikinick, there was neither grass nor weed, and only tiny, thinly scattered sun-gold reached the brown matted floor.[1]

After self-thinning has gone on for a hundred years or so, the ranks have been so thinned that there are openings sufficiently large to allow other species a chance to come in. By this time, too, there is sufficient humus on the floor to allow the seeds of many other species to germinate. Lodge-pole thus colonizes barren places, holds them for a time, and so changes them that the very species dispossessed by fire may regain the lost territory. Roughly, the lodge-pole will hold the ground exclusively from seventy-five to one hundred and fifty years, then the invading trees will come triumphantly in and, during the next century and a half, will so increase and multiply that they will almost exclude the lodge-pole. Thus Engelmann spruce and Douglas fir are now growing where lodge-pole flourished, but let fire destroy this forest and lodge-pole will again claim the territory, hold it against all comers for a century or two, and then slowly give way to or be displaced by the spruces and firs.

The interesting characteristic of holding its cones and hoarding seeds often results in the cones being overgrown and embedded in the trunk or the limbs of the trees. As the cones hug closely the trunk or the limbs, it is not uncommon for the saw, when laying open a log at the mill, to reveal a number of cones embedded there. I have in my cabin a sixteen-foot plank that is two inches in diameter and six inches wide, which came out of a lodge-pole tree. Embedded in this are more than a score of cones. Probably most of these cones were of the first crop which the tree produced, for they clung along the trunk of the tree and grew there when it was about an inch and a quarter in diameter. The section upon which these cones grew was between fifteen and twenty-five feet from the ground.

The seeds of most conifers need vegetable mould, litter, or vegetation cover of some kind in which to germinate, and then shade for a time in which to grow. These requirements so needed by other conifer seeds and seedlings are detrimental to the lodge-pole. If its seeds fall on areas lightly covered with low huckleberry vines, but few of them will germinate. A lodge-pole seed that germinates in the shade is doomed. It must have sunlight or die. In the ashes of a forest fire, in the full glare of the sun, the seeds of the lodgepole germinate, grow, and flourish.

Wind is the chief agency which enables the seeds to migrate. The seeds are light, and I know of one instance where an isolated tree on a plateau managed to scatter its seeds by the aid of the wind over a circular area fifty acres in extent, though a few acres is all that is reached by the average tree. Sometimes the wind scatters the seeds unevenly. If most of the seeds are released in one day,

and the wind this day prevails from the same quarter, the seeds will take but one course from the tree; while changing winds may scatter them quite evenly all around the tree.

A camping party built a fire against a lone lodge-pole. The tree was killed and suffered a loss of its needles from the fire. Four years later, a long green pennant, tattered at the end and formed of lodge-pole seedlings, showed on the mountain-side. This pennant began at the tree and streamed out more than seven hundred feet. Its width varied from ten to fifty feet.

The action of a fire in a lodge-pole forest is varied. If the forest be an old one, even with much rubbish oh the ground the heat is not so intense as in a young growth. Where trees are scattered the flames crawl from tree to tree, the needles of which ignite like flash-powder and make beautiful rose-purple flames. At night fires of this kind furnish rare fireworks. Each tree makes a fountain of flame, after which, for a moment, every needle shines like incandescent silver, while exquisite light columns of ashen green smoke float above. The hottest fire I ever experienced was made by the burning of a thirty-eight-year lodge-pole forest. In this forest the poles stood more than thirty feet high, and were about fifteen thousand to an acre. They stood among masses of fallen trees, the remains of a spruce forest that had been killed by the same fire which had given this lodge-pole forest a chance to spring up. Several thousand acres were burned, and for a brief time the fire traveled swiftly. I saw it roll blazing over one mountain-side at a speed of more than sixty miles an hour. It was intensely hot, and in a surprisingly short time the flames had burned every log, stump, and tree to ashes. Several hundred acres were swept absolutely bare of trees, living and dead, and the roots too were burned far into the ground.

Several beetles prey upon the lodge-pole, and in some localities the porcupine feeds off its inner bark. It is also made use of by man. The wood is light, not strong, with a straight, rather coarse grain. It is of a light yellow to nearly white, or pinkish white, soft, and easily worked. In the West it is extensively used for lumber, fencing, fuel, and log houses, and millions of lodge-pole railroad-ties are annually put to use.

Most lodge-poles grow in crowded ranks, and slow growth is the result, but it is naturally a comparatively rapid grower. In good, moist soil, uncrowded, it rapidly builds upward and outward. I have more than a score of records that show that it has made a quarter of an inch diameter growth annually, together with an upright growth of more than twelve inches, and also several notes which show where trees standing in favorable conditions have made half an inch diameter growth annually. This fact of its rapid growth, together with other valuable characteristics and qualities of the tree, may lead it to be selected by the government for the reforestation of millions of acres of denuded areas in the West. In many places on the Rockies it would, if given a chance, make commercial timber in from thirty to sixty years.

I examined a lodge-pole in the Medicine Bow Mountains that was scarred by fire. It was two hundred and fourteen years of age. It took one hundred and seventy-eight years for it to make five inches of diameter growth. In the one hundred and seventy-eighth ring of annual growth there was a fire-scar, and during the next thirty-six years it put on five more inches of growth. It is probable, therefore, that the fire destroyed the neighboring trees, which had dwarfed and starved it and thus held it in check. I know of scores of cases where lodge-poles grew much more rapidly, though badly fire-scarred, after fires had removed their hampering competitors.

There are millions of acres of young lodge-pole forests in the West. They are almost as impenetrable as canebrakes. It would greatly increase the rate of growth if these trees were thinned, but it is probable that this will not be done for many years. Meantime, if these forests be protected from fire, they will be excellent water-conservers. When the snows or the rains fall into the lodge-pole thickets, they are beyond the reach of the extra dry winds. If they are protected, the water-

supply of the West will be protected; and if they are destroyed, the winds will evaporate most of the precipitation that falls upon their areas.

I do not know of any tree that better adjusts itself to circumstances, or that struggles more bravely or successfully. I am hopeful that before many years the school-children of America will be well acquainted with the Lodge-Pole Pine, and I feel that its interesting ways, its struggles, and its importance will, before long, be appreciated and win a larger place in our literature and also in our hearts.

CHAPTER TWENTY-NINE: OF AQUACULTURE AND MARICULTURE

Definitions: Aquaculture requires fresh water, Mariculture requires salt water

Aquaculture is agriculture undertaken in fresh water. *Mariculture* is agriculture undertaken in the salt water. Animals, plants, and microorganisms are cultivated in aquaculture and mariculture, and are integrated with terrestrial agriculture.

Blue-Green algae

The algaes are one of the most important and useful microorganisms that are cultivated. Algae sometimes form immense colonies, but also sometimes live solitary lives.

Blue-Green Algae are more properly understood to be cyanobacteria. The Encyclopedia Britannica Online (2009, http://www.britannica.com /EBchecked/topic/70231/blue-green-algae) describes these ancient and interesting creatures as being...

"...any of a large, heterogeneous group of prokaryotic, principally photosynthetic organisms. Cyanobacteria resemble the eukaryotic algae in many ways, including morphological characteristics and ecological niches, and were at one time treated as algae, hence the common name of blue-green algae. Algae have since been reclassified as protists, and the prokaryotic nature of the blue-green algae has caused them to be classified with bacteria in the prokaryotic kingdom Monera.

Like all other prokaryotes, cyanobacteria lack a membrane-bound nucleus, mitochondria, Golgi apparatus, chloroplasts, and endoplasmic reticulum. All of the functions carried out in eukaryotes by these membrane-bound organelles are carried out in prokaryotes by the bacterial cell membrane. Some cyanobacteria, especially planktonic forms, have gas vesicles that contribute to their buoyancy. Chemical, genetic, and physiological characteristics are used to further classify the group within the kingdom. Cyanobacteria may be unicellular or filamentous. Many have sheaths to bind other cells or filaments into colonies.

Cyanobacteria contain only one form of chlorophyll, chlorophyll a, a green pigment. In addition, they contain various yellowish carotenoids, the blue pigment phycobilin, and, in some species, the red pigment phycoerythrin. The combination of phycobilin and chlorophyll produces the characteristic blue-green colour from which these organisms derive their popular name. Because of the other pigments, however, many species are actually green, brown, yellow, black, or red.

Most cyanobacteria do not grow in the absence of light (i.e., they are obligate phototrophs); however, some can grow in the dark if there is a sufficient supply of glucose to act as a carbon and energy source.

In addition to being photosynthetic, many species of cyanobacteria can also "fix" atmospheric nitrogen—that is, they can transform the gaseous nitrogen of the air into compounds that can be used by living cells. Particularly efficient nitrogen fixers are found among the filamentous species that have specialized cells called heterocysts. The heterocysts are thick-walled cell inclusions that are impermeable to oxygen; they provide the anaerobic (oxygen-free) environment

necessary for the operation of the nitrogen-fixing enzymes. In Southeast Asia, nitrogen-fixing cyanobacteria often are grown in rice paddies, thereby eliminating the need to apply nitrogen fertilizers.

Cyanobacteria range in size from 0.5 to 60 micrometres, which represents the largest prokaryotic organism. They are widely distributed and are extremely common in fresh water, where they occur as members of both the plankton and the benthos. They are also abundantly represented in such habitats as tide pools, coral reefs, and tidal spray zones; a few species also occur in the ocean plankton. On land, cyanobacteria are common in soil down to a depth of 1 m (39 inches) or more; they also grow on moist surfaces of rocks and trees, where they appear in the form of cushions or layers.

Cyanobacteria flourish in some of the most inhospitable environments known. They can be found in hot springs, in cold lakes underneath 5 m of ice pack, and on the lower surfaces of many rocks in deserts. Cyanobacteria are frequently among the first colonizers of bare rock and soil. Various types of associations take place between cyanobacteria and other organisms. Certain species, for example, grow in a mutualistic relationship with fungi, forming composite organisms known as lichens.

Cyanobacteria reproduce asexually, either by means of binary or multiple fission in unicellular and colonial forms or by fragmentation and spore formation in filamentous species. Under favourable conditions, cyanobacteria can reproduce at explosive rates, forming dense concentrations called blooms. Cyanobacteria blooms can colour a body of water. For example, many ponds take on an opaque shade of green as a result of overgrowths of cyanobacteria, and blooms of phycoerythrin-rich species cause the occasional red colour of the Red Sea. Cyanobacteria blooms are especially common in waters that have been polluted by nitrogen wastes; in such cases, the overgrowths of cyanobacteria can consume so much of the water's dissolved oxygen that fish and other aquatic organisms perish."

Algae is grown for food, medicine, animal feed and energy. Spirulina, a kind of algae, has already been introduced in the chapter of Animal Husbandry as a kind of animal feed. Wikipedia Online Encyclopedia describes Spirulina as

"the common name for human and animal food supplements produced primarily from two species of cyanobacteria: Arthrospira platensis, and Arthrospira maxima. These and other Arthrospira species were once classified in the genus Spirulina. There is now agreement that they are a distinct genus, and that the food species belong to Arthrospira; nonetheless, the older term Spirulina remains the popular name. Spirulina is cultivated around the world, and is used as a human dietary supplement as well as a whole food and is available in tablet, flake, and powder form. It is also used as a feed supplement in the aquaculture, aquarium, and poultry industries.

Spirulina are free-floating filamentous cyanobacteria characterized by cylindrical, multicellular trichomes in an open left-hand helix. Spirulina occurs naturally in tropical and subtropical lakes with high pH and high concentrations of carbonate and bicarbonate. A. platensis occurs in Africa, Asia and South America, whereas A. maxima is confined to Central America.

Spirulina is believed to have been a food source for the Aztecs and other Mesoamericans until the 16th-century; its harvesting from Lake Texcoco and subsequent sale as cakes is described by one of Cortés' soldiers (Díaz Del Castillo, B. The Discovery and Conquest of Mexico, 1517-1521. London: Routledge, 1928, p. 300). The Aztecs called it Tecuitlatl, meaning stone's excrement. Spirulina was found in abundance at the lake by French researchers in the 1960s, but there is no reference to its use there as a daily food source after the 16th century. The first large-scale Spirulina production plant, run by Sosa Texcoco, was established there in the early 1970s.

Leo Szilard postulated the development of algae-based food supplements (which he called "Amruss") in his 1961 short story, The Voice of the Dolphins.

Spirulina may have an even longer history in Chad, as far back as the 9th century Kanem Empire. It is still in daily use today, dried into cakes called Dihé, which are used to make broths for meals, and also sold in markets. The Spirulina is harvested from small lakes and ponds around Lake Chad.

Most cultivated spirulina is produced in open-channel raceway ponds, with paddle-wheels used to agitate the water. The largest commercial producers of spirulina are located in the United States, Thailand, India, Taiwan, China, Pakistan and Burma (a.k.a. Myanmar).

Spirulina is highly nutritious, containing great quantities of essential fatty acids, vitamins and minerals. It also shows great promise in many medical applications, ranging from the treatment of retroviruses and cancer, to cholesterol and blood pressure. The United Nations World Food Conference in 1974 called Spirulina "the best food for the future." It is very good food, affordable to produce, but has very poor palatability.

Animals will eat it both as a supplement and as a feed if they are trained to eat it and accustomed to it - just as they will eat turnips, if raised on it.

Cultivation of Spirulina is very easy. A live culture of the bacteria is bought from one of the many vendors or farmers already growing it and brought to a saltwater pond, fed and then, at harvest, the bacteria is skimmed out of the water and dehydrated into cakes. The bacteria requires tropical conditions, so in temperate or subarctic or arctic climates, it must be grown in a greenhouse.

Grow Your Own Spirulina (2001, http://www.antenna.ch/en/ documents/Jourdan_UK.pdf) by Jean-Paul Jourdan and translated by the author for Antenna Technologies provides an excellent instruction to the beginner. Jourdan, according to his publisher, "spent more than 12 years working on the development of low-cost techniques of spirulina production. After a career in the chemical industry, he devoted his retirement time in the south of France, with the goal to participate in making spirulina available to the children in developing countries. He worked with Ripley Fox and Francisco Ayala, became a member of Technap, and collaborated closely with Antenna Technologies and several other NGOs working on spirulina" with the noble intention of feeding those without food.

Temperature is the most important climatic factor influencing the rate of growth of spirulina. Below 20°C, growth is practically nil, but spirulina does not die. The optimum temperature for growth is 35°C, but above 38°C spirulina is in danger.

Growth only takes place in light (photosynthesis), but illumination 24 hours a day is not recommended. During dark periods, chemical reactions take place within spirulina, like synthesis of proteins and respiration.

Respiration decreases the mass of spirulina ('biomass') ; its rate is much greater at high temperature so cool nights are better on that account, but in the morning beware that spirulina cannot stand a strong light when cold (below 15°C). Light is an important factor but full sunlight may not the best rate of illumination : 30% of full sun light is actually better, except that more may be required to quickly heat up the culture in the morning.

Individual spirulina filaments are destroyed by prolonged strong illumination ('photolysis'), therefore it is necessary to agitate the culture in order to minimize the time they are exposed to full sunlight. Rain is beneficial to compensate for evaporation, but it must not be allowed to cause overflowing of the culture pond.

Wind is beneficial for agitating and aerating the culture, but it may bring dirt into it. Artificial light and heating may be used to grow spirulina, although they are not economical. Fluorescent tubes and halogen lamps are both convenient. Lamps can illuminate and heat the culture simultaneously.

Spirulina thrives in alkaline, brackish water. Any water-tight, open container can be used to grow spirulina, provided it will resist corrosion and be non-toxic. Its shape is immaterial, although sharp angles should be avoided to facilitate agitation and cleaning. Its depth is usually 40 cm (twice the depth of the culture itself). It can be as small as 1m² but 5, 20 or 100 m² are more economical. Dimensions are only limited by the necessity of accessing for agitation and cleaning. The bottom should have a slight slope and a recess to facilitate emptying. Two ponds are better than just one, for practical reasons. The most economical ponds are made of U.V. resistant plastic film of 0.5 mm thickness or more (PVC or polycthylene), with sides supported by bricks or a wooden structure or metal tubes. If termites are present, a layer of dry ash plus a layer of sand should be placed under the film to protect it.

Concrete ponds are of course a good, durable solution where experienced labour is available. Before starting the culture, the cement should be well cured and whitewashed. A greenhouse over the ponds offers many advantages, provided it can be aerated and shaded. As a matter of fact, covering the ponds is practically necessary.

Agitation can be manual, with a plastic broom, once every two hours. If electricity is available, aquarium pumps are practical to agitate the surface of the culture (one watt/m² is enough). Raceway ponds agitated by paddlewheels are standard in the industry, but somewhat outside the scope of this manual.

Spirulina can live in a wide range of compositions of water; the following is a convenient analysis:

Anions

Carbonate 2800 mg/l
Bicarbonate 720 mg/l
Nitrate 614 mg/l
Phosphate 80 mg/l
Sulfate 350 mg/l
Chloride 3030 mg/l

Cations

Sodium 4380 mg/l
Potassium 642 mg/l
Magnesium 10 mg/l
Calcium 10 mg/l
Iron 0.8 mg/l

Total dissolved solids 12847 mg/l
Density @ 20°C 1010 g/l
Alcalinity 0.105 N (moles strong base/liter)
pH @ 20°C 10.4

In addition, the solution contains traces of all micronutrients necessary to support plant life. Such solution can be obtained by disolving various combinations of chemicals...

...The water used should be clean or filtered to avoid foreign algae. Potable water is convenient. Water often contains enough calcium, but if it is too hard it will cause muds which are more a nuisance than a real problem.

Brackish water may be advantageous but should be analyzed for its contents or tested. Seawater can be used under some very special conditions, outside the scope of this short manual...

...Seeding:

Choose a spirulina strain containing a high proportion of coiled filaments (less than 25% straight filaments, if possible none at all), easy to harvest, and containing at least 1% of gamma-linolenic acid (GLA)based on dry weight. Concentrated spirulina seed culture can be obtained either from the floating layer of an unagitated culture, or by rediluting a freshly filtered biomass (beware of lumps). A concentration of up to 3 g spirulina (dry) per liter is permissible if storage and transportation last less than a week's time, and provided the seed culture be aerated at least two times a day. If aeration can be continuous, the concentration may be up to 10g/l (weights of spirulina always refer to contained dry matter).

It is advisable to maintain the growing culture at a fairly high concentration in spirulina after each dilution with culture medium, about 0.3 g/l : the Secchi disk reading should not be above 5 cm, i.e. the color of the culture should stay clearly green (otherwise shading is mandatory). The rate of growth is about 30%/day when the temperature is adequate and the make-up culture medium based on bicarbonate (without carbonate). As the growth is proportional to the area of the culture exposed to light, it is recommended to maximize this area at all times (i.e. use the minimum feasible depth during the expanding area period, generally 5 to 10 cm).

When the final area and depth (10 to 20 cm) are reached in the pond, let the spirulina concentration rise to about 0.5 g/l (Secchi disk at about 2 cm) before harvesting.

Harvesting:

When the spirulina is in good condition, separating it from the water ('harvesting') is an easy operation, but when it gets too old and 'sticky' harvesting may become a nightmare. The best time for harvesting is early morning for various reasons:

- the cool temperature makes the work easier,
- more sunshine hours will be available to dry the product,
- the % proteins in the spirulina is highest in the morning.

There are basically two steps in harvesting :

- filtration to obtain a 'biomass' containing about 10 % dry matter (1 liter = 100 g dry) and 50 % residual culture medium,
- removal of the residual culture medium to obtain the 'fresh spirulina biomass', ready to be consumed or dried, containing about 20 % dry matter and practically no residual culture medium.

Filtration is simply accomplished by passing the culture through a fine weave cloth, using gravity as the driving force. Synthetic fiber cloth (especially polyamide or polyester) with a mesh size of about 30 to 50 microns is the preferred filtering medium.

Supporting the filtration cloth by a fine net will accelerate somewhat the filtration and protect the cloth against rupturing, but a simple bag made from the cloth works well also.

The filter can be installed above the pond to directly recycle the filtrate. The culture to be harvested should be passed through a sieve (mesh size about 200 µ) to remove any foreign matter such as insects, larvae, leaves and lumps of polysaccharide or mud. When the spirulina floats, it is efficient to scoop out the 'cream', using a straight edge pail. Harvesting the floating layer (generally richer in spiraled spirulina) will tend to increase the % straight spirulina in the culture. Straight spirulina is more difficult to harvest. So actually it is not recommended to harvest the floating layer.

The filtration is accelerated by gently moving or scraping the filter. When most of the water has filtered through, the biomass will often agglomerate into a "ball" under the motion, leaving the cloth clean (this desirable condition happens mostly when the biomass is richer in spiraled forms and the culture medium is clean). Otherwise it may then be necessary to scrape it out from the cloth.

The final dewatering is accomplished by pressing the biomass enclosed in a piece of filtration cloth plus a strong cotton cloth, either by hand or in any kind of press. The simplest is to apply pressure (0.15 kg/cm² is enough) by putting a heavy stone on the bag containing the biomass. The "juice" that is expelled comes out first colorless, later it turns green and the operation must then be discontinued otherwise too much product will be lost. For the usual thickness of cake (about one inch after pressing), the pressing time is about 15 minutes. Practically all the interstitial water (culture medium) is removed, and some rinsing may be effected by the internal juices from ruptured cells.

The pH of the well pressed biomass is near 7 (neutrality). This pressing operation effects a more efficient separation of the residual culture medium than washing the biomass with its weight of water on the filter. Washing with fresh water may cause rupture of the cell wall of the spirulina due to osmotic shock, leading to loss of valuable products; it may also introduce germs contained in the wash water. Washed biomass is a lot more prone to fermentation than pressed biomass. Pressed biomass contains twice as much dry matter as unpressed biomass, which reduces the drying time.

When the biomass is too "sticky", for instance 100% straight filaments, it may not be possible to dewater it : in such case, it must be washed. The nutrients extracted from the culture medium by the harvested biomass should be replaced to maintain the fertility of the culture medium.

The main nutrient is carbon, which is spontaneously absorbed by the medium from the air, as carbon dioxide (CO_2), whenever the pH of the medium is above 10. However the air contains so little CO2 that this absorption is a slow process, corresponding to a maximum productivity of 4 g spirulina/day/m². This maximum rate is reached at or above pH = 10.5. Extra CO_2 can be introduced to increase the productivity, either pure CO2 gas (from fermentation or from a cylinder) or dissolved organic matter that can be biologically oxidised to CO_2 like sugar. The gas is bubbled into the medium, under a piece of floating plastic film (about 4 % of the total area of the pond).

Another popular, although costly, means of feeding carbon is bicarbonate. Adding bicarbonate is an easy and efficient way of reducing the pH, but it increases the salinity; to maintain the salinity, it is mandatory to drain part of the culture medium from time to time and replace it by new medium rich in bicarbonate. Disposal of the drained medium may be an environmental problem and the cost may of the chemical can be uneconomical.

The amount of gas, sugar or bicarbonate to be fed is adjusted so as to control the pH at around 10.4. A pH lower than 10.2 may cause an overproduction of undesirable, but not dangerous, exopolysacharide (EPS). A good practical dose of carbon feed is the equivalent of 40 % of the spirulina produced (i.e. about 0.8 kg of CO2 or 0.4 kg of sugar per kg of dry spirulina harvested). Sugar may induce some degradation of the culture medium, so actually it is recommended to feed less than 0.3 kg/kg, and as regularly as possible.

Apart from carbon, spirulina requires the usual major biological nutrients : N, P, K, S, Mg, Ca, Fe, plus a number of micronutrients. In many cases, the micronutrients and the calcium need not be fed to the culture, being supplied as natural impurities contained in the make-up water and the chemicals used as food for the spirulina. In some locations, the water contains a large excess of calcium, magnesium or iron that may become a nuisance by producing abundant muds.

The major nutrients can be supplied in various ways, preferrably in a soluble form, but even insoluble materials will slowly be disolved as the corresponding ions are consumed by the spirulina in the medium. Availability

and cost are the main criterions for selecting the sources of nutrients, but their content in valuable micronutrients may also affect the choice...

...In case of necessity ('survival' type situations), all major nutrients and micronutrients except iron can be supplied by urine (from persons or animals in good health, not consuming drugs) at a dose of about 15 to 20 liters/ kg spirulina. Iron can be supplied by a saturated solution of iron in vinegar (use about 100 ml/kg) plus some lemon juice. Ferilizers other than urea can be fed every month or so, but urea (or urine) has to be fed daily, based on the average production expected.

Apart from harvesting and feeding, a spirulina culture requires some attention in order to be kept in good condition. Agitation is a requisite. Continuous agitation however is not required. One third of full sun will saturate the photosynthetic capacity of spirulina, but shading is not required except to reduce the consumption of water (evaporation) or the temperature (< 38°C) or the pH (< 11.3). The temperature will practically never be too high, but the pH may soon become too high if insufficient carbon is supplied.

The depth of culture must be kept between 10 and 20 cm. Evaporation must be compensated for by adding water. Rains must be compensated for either by evaporation or by draining part of the medium (in the latter case, add the chemicals corresponding to the volume of medium drained).

If too much mud accumulates at the bottom of the pond, it can be removed by pumping or siphoning (preferrably while the spirulina is floating, in order to reduce the loss). Add new culture medium to replace the volume removed. Of course another way to remove the muds is to provisionally transfer the culture into another pond and clean the bottom.

Accumulation of muds may cause 'white skins' to float in the afternoon when the temperature of the culture goes above 35°C. These are not harmful as they will go back to the bottom again during the night, but their appearance is unpleasant: they can be removed using a net.

In large industrial spirulina farms, continuous monitoring of the elements contained in the culture medium makes the exact make-up of individual micronutrient possible. But this is too costly for small scale operators, who then have to rely on renewing the culture medium or on the addition of minor amounts of a concentrated solution of micronutrients as mentioned above.

Excessive production of exopolysaccharide (EPS) by the spirulina or its too slow biodegradation will cause 'stickiness' of the biomass and/or a flocculation of spirulina into undesirable aggregates. To control this, maintain higher pH, nitrogen and iron contents in the culture medium. The pH should be above 10, preferrably above 10.3.

Partial or total renewal of the culture medium also helps remedy the 'stickiness' of the biomass. Excessive turbidity of the filtrate may be reduced by slowing down the growth of spirulina. This applies to the organic muds and EPS also. The culture is an ecosystem inside which various microorganisms (useful bacteria and zooplankton) live in symbiosis, resulting in a continuous, but slow, cleaning effect of the medium. If pollutants are produced more rapidly than this biological cleansing system can absorb, renewal of the medium will be necessary to keep it clean. Slowing down the growth may be obtained by shading or by reducing the rate of harvesting.

When stressed by a pH or salinity sudden variation, for instance by a heavy rain (more than 10% of the culture volume), the spirulina may sink to the bottom of the pond, where they will be in great danger of dying from suffocation. In order to facilitate their recovery, agitate the bottom often to give them more chance to disentangle from the muds.

The culture may become colonized by predators living on spirulina, like larvae of mosquitoes and Ephydra flies, or amoebas. In our experience these invaders cause no other trouble than reducing somewhat the productivity. Often they can be controlled by increased salinity, pH or temperature, or they disappear by themselves after a few weeks.

If the concentration of spirulina is too low, the culture may be invaded by chlorella (a unicellular, edible alga). Fortunately, chlorella sinks to the bottom of the pond: momentarily stopping the agitation will deprive chlorella from light and it will eventually die. The same applies to diatoms.

Toxic algae like anabaena, anabaenopsis arnoldii and microcystis do not grow in a well tended spirulina culture, but for safety's sake it is recommended to have the culture checked by a microscopic examination at least once a year. A culture of young artemias can be used to check the absence of toxic algae : add a little of the spirulina culture to be checked (10 % of the artemias culture) and observe the small animals ; if they retain their vitality for at least 6 hours, there is no toxic algae. Artemias eggs are sold by aquariophilic stores.

Usual pathogenic bacteria do not survive the high pH (> 9.7) of a spirulina culture in production ; however a microbiological assay of the product should be made also at least once a year. Contaminations most generally occur during or after harvesting.

The color of the culture should be deep green. If it turns yellowish, this may be due to either a lack of nitrogen or an excess of light (photolysis) or of ammonia (excess of urea). In the latter two cases recovery is generally possible within two weeks while resting the culture under shading.

There is no question that freshly harvested, pressed biomass is superior to any other form of spirulina. However it will not keep more than a few days in the refrigerator, and no more than a few hours at room temperature. Adding 10 % salt is a way to extend these keeping times up to several months, but the appearance and taste of the product change : the blue pigment (phycocyanin) is liberated, the product becomes fluid and the taste is somewhat like anchovy's paste.

Freezing is a convenient way to keep fresh spirulina for a long time. It also liberates the blue pigment, but it does not alter the taste. Drying is the only commercial way to store and distribute spirulina. If suitably packaged and stored, dry spirulina is considered good for consumption up to five years. But drying is an expensive process and it very generally gives the product a different and possibly unpleasant taste and odour. Dried spirulina is also not so easy to use.

The industrial type of spirulina dryer is the spray drier which flash dries fine droplets at very high temperature and yields an extremely fine powder of low apparent density. This type is outside the reach of artisanal producers. So is freeze drying, the best way of drying but far too expensive and complicated.

Sun drying is the most popular among small producers, but requires a few precautions. Direct sun drying must be very quick, otherwise the chlorophyll will be destroyed and the dry product will appear blueish.

Whatever the source of heat, the biomass to be dried must be thin enough to dry before it starts fermenting. Basically two types of shapes are used : thin layers of rather fluid biomass laid on a plastic film, and rods ('spaghetti') laid on a perforated tray. In the former case the air flows horizontally over the film, while in the latter one it flows vertically through the tray. The rod shape is theoretically better as evaporation can take place all around; rods are obtained by extrusion to a diameter of 1 to 2 mm. But rods must be sturdy enough to maintain their shape, so this type of drying is restricted to biomasses that can be dewatered by pressing into a firm consistency.

Warm, dry air passed over or through the biomass to be dried must have a high velocity at the beginning of the drying process. Later on in the process the velocity of the air is less important than its dryness (therefore it is usual to end up with air heated at 65°C) The total duration of the drying should not exceed a few hours, preferrably 2 hours.

During the drying process as well as afterwards the product must be protected against contaminations from dust and insects and should not be touched by hands. Drying temperature should be limited to 68°C, and drying time to 7 hours. Incipient fermentation during drying can be detected by smelling during the drying process as well as

afterwards. However it is customary that a rather strong smell evolves from the biomass at the very beginning of the drying.

The dry chips or rods are usually converted to powder by grinding in order to increase their apparent density. The best storage is in heat sealed, aluminized plastic bags.

Those persons who cannot stand the taste and odour of spirulina most probably were once exposed to a low quality product. Good quality fresh spirulina is so bland it can replace butter on toasts and can enrich almost any dish; cold drinks can be prepared by mixing it with fruit juices. Fresh spirulina is a paste easily mixed, diluted, extruded, etc.

There are literally thousands of possible recipes making use of spirulina either fresh, frozen or dry, raw or cooked. Above 70°C the gorgeous green color often turns brown in the presence of water. So you can choose your preferred color for soups and sauces.

MEASURING THE CONCENTRATION IN SPIRULINA WITH THE SECCHI DISK:

The Secchi disk is a self-made instrument: a piece of white plastic fixed at the tip of a graduated rod. Dip it vertically into the spirulina culture until you just cannot see the white piece; the reading in centimeters gives an approximate value of the concentration. If the medium itself (the filtrate) is turbid, use the appropriate curve, after measuring the turbidity of the filtrate using a black Secchi disk, expressed in cm in the same way as the concentration.

As the reading depends on the eye of the operator, everyone should make his own graph, based on absolute measurements of the concentration (by filtering a given amount, drying in the oven and weighing). The reading also depends on the shape of the filaments.

Jourdan warns against the use of chemical fertilizers and especially heavy metals that may be present in them or in the environment: algae readily absorbs these heavy metals. He advocates the use of minerals and soils to feed the bacteria in a formula "supplied by Antenna Technologies, Geneva, upon request."

He also discusses harvesting using a cloth:

When most of the water has filtered through, the biomass will agglomerate into a ball under motion of the filtering cloth, leaving the cloth clean (this desirable condition happens when the biomass is richer in spiraled forms and the culture medium is clean).

At this stage the biomass contains 10 % dry matter and it has a soft consistency ; it will not stick to plastic materials but glide on it. Final dewatering of the biomass is accomplished by pressing the biomass enclosed in a piece of filtration cloth, either by hand or in any kind of press. The simplest is to apply pressure (0.15 kg/cm^2 is enough) by putting a heavy stone on the bag containing the biomass. The juice that is expelled comes out clear and colorless, and the operation must then be discontinued when no more liquid drops out. For the usual thickness of cake (about one inch after pressing), the pressing time is about 15 minutes. Practically all the interstitial water (culture medium) is removed. The pH of the pressed biomass is near 8 and may even be brought below due to breakage of some spirulina cells, but it is not advisable to bring it too low.

This pressing operation effects a more efficient separation of the residual culture medium than washing the biomass.. Washing with fresh water may cause rupture of the cell wall of the spirulina due to osmotic shock, leading to loss of valuable products; it may also introduce germs contained in the wash water. Pressed biomass contains twice as much dry matter as unpressed biomass, which reduces the drying time. It has a firm consistency (can be cut by a knife like cheese). It can be eaten as is.

The biomass to be dried must be thin enough to dry before it starts fermenting. It is extruded into fine rods ('spaghetti') of a diameter of 1 to 2 mm onto a plastic perforated tray (or nylon mosquito net). The rods must be sturdy enough to maintain their shape, so this type of drying is restricted to biomasses that can be dewatered by pressing into a firm consistency. In India the indiappam makker kitchen instrument can be used for extruding (the wooden type is preferred to the aluminum one).

During the drying process as well as afterwards the product must be protected against contaminations from dust and insects and should not be touched by hands. Drying temperature should be limited to 68°C, and drying time to 7 hours. With good ventilation and low charge (1 kg fresh rods/m² of tray) the drying time may be reduced to 2 hours. The final % water should be less than 9. The dry product detaches itself easily from the tray.

Incipient fermentation during drying can be detected by smelling during the drying process as well as afterwards. The dry rods are usually converted to powder by grinding in order to increase their apparent density. The best storage is under vacuum in heat sealed, aluminized plastic bags.

Though algae has no roots, the principles of Tullian farming still apply. It is important to feed the bacteria, and ensure they have access to the food. The act of aeration and stirring improves the ability of each individual bacteria to eat, decreases "weed" bacteria, and allows a more efficient use of atmospheric chemicals to augment production.

Nutritional value of blue-green algae

Blue-green algae is very nutritious:

Macronutrients	
Calories (kcal/kg)	290
Moisture	4.68%
Crude Protein	57.5%
Fat	0.0%
Crude Fiber	*
ADF	*
NDF	*
Minerals	
Calcium	0.12%
Phosphorus	0.12%
Iron	0.0285%
Zinc	0.0020%
Magnesium	0.20%
Manganese	0.0019%
Copper	0.0061%
Selenium	0.0007%
Potassium	1.36%
Cobalt	*
Sulfur	*
Vitamins	
Vitamin A, IU	570.00
Vitamin E, IU	5.00

Red, Brown and Green Algaes

Red, brown and green algae, also known as "seaweed," are also highly promising animal and human food. These algae differ from the blue green algae in that they are multicellular organisms.

Unlike their unicellular cousins, the seaweeds are highly adapted and there is a variety for nearly any kind of water in nearly every environment. It can grow above sea level (some varieties need only regular misting or tidal activity, tolerating dehydration), or at the limit of sea sunlight penetration. Deeper varieties are also known as "kelp," the brown algaes.

Seaweeds are popular human cuisine in nearly all coastal areas where they grow, and are used either as main courses, spices or sometimes in drinks. They are typically consumed as a vegetable, either fresh in salads or cooked with grains, or dehydrated. They are as medicinal as the blue green algae, but because of their multicellularism, are infinitely easier to bring under agricultural cultivation.

Some algae are used for oil production. The oil is extracted out and burned for energy. This does not affect the growing methods, but presents another use for this very useful organism.

There are thousands of varieties of seaweed, and each requires its own growing conditions, its own cultivation methods and its own harvesting techniques; often, wild species are brought under domestication if there are no algae farms already in operation nearby for the would-be farmer to study. Many are cultivated in artificial or improved natural bays. They are, generally, highly productive and require little labor.

Some seaweeds require an anchorage (the only function of their primitive roots), but others float freely. As such they do not require tillage. Depending on the variety, they are sometimes anchored to ropes (their spores are seeded onto the ropes, and the ropes buoyed in a harbor at the appropriate depth), seeded on the floor of a bay or onto other media. In this sense, the cultivation of seaweed is much like mushroom cultivation: spores are presented with ideal growing conditions, harvested when ripe and some are allowed to undertake reproductive cycles so their spores may be saved for future harvests.

Kelp, because of the depth at which it is anchored, is grown somewhat differently. The variety Giant Kelp is easily harvested at the surface by boats because it will grow back after being harvested and tends to be self-sustaining: it is harvested in the wild under wild conditions with little or no cultivation.

Kelp "forests" are valuable biodiverse environments, but kelp has great value to human industry as well. It is highly useful in industrial applications because it accumulates sodium carbonate in its tissues, which may be obtained later by harvesting the kelp and burning it. It is also a good source for iodine and alkali, for uses in soap, textile and paper production and glass manufactures. In the 19th Century, the Leblanc process was developed that used coal to yield sodium carbonate more affordably than kelp derived sodium carbonate, and now kelp is more used for medicines, foods and feeds.

Iodine is an important nutrient in the Atomic age. Traditionally (and in modern times) iodine has been used to cure goiter and cretinism. Goiter is an inflammation of the thyroid gland, the goiter. Cretinism is, according to the medical journal, *the Lancet* (372 (9633): 88. July 12, 2008) one of the leading cause of preventable mental retardation, producing typical reductions in IQ of 10 to 15 IQ points. These diseases are typically cured by adding small amounts of iodine to table salt, the iodine comes from kelp or dehydrated seawater.

Potassium Iodide (KI) is used to prevent fungal infections of animal feeds and human foods, in fortified table salt to prevent goiter and cretinism, and, very importantly, in the treatment of radioactive fallout victims to help their bodies detoxify the radioactive wastes and prevent the radioactive wastes from accumulating in their bodies. Such victims over 12 years of age should receive 130 mg KI, 3 to 12 years of age 65 mg, 1 to 36 months old 32 mg and less than 1 month olds should receive 16 mg. As nuclear fallout can travel thousands of miles and last hundreds of years, kelp (a source of KI) is more important than ever before in human history: even though few people are exposed to the intense radiation of an accident or bomb, low doses over long periods of time are dangerous. Even nuclear tests can spread dangerous dust world-wide for years after they have been undertaken!

Kelp can contain about 0.06% iodine by dry weight, and to consume 65 mg would require eating about 1/20 of a dry ounce.

Of course, greater exposure to nuclear waste would require greater doses of medicine, but caution should be exercised: excess iodine to a body not accustomed to eating it can cause swelling of the Parotid saliva gland (located at the back of the throat).

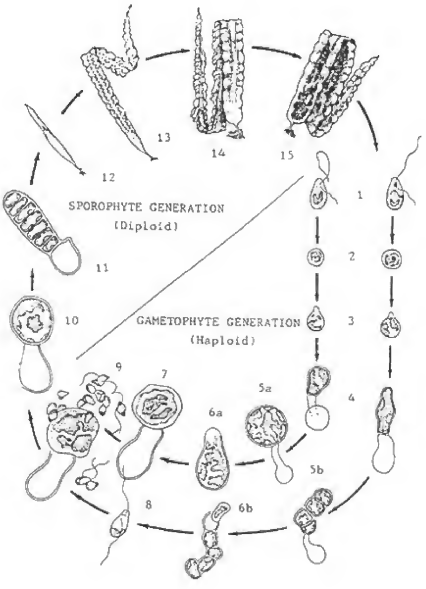
Kelp also produces quantities of Alginate, a thickening agent used in culinary purposes in place of gums to make ice creams, jellies, salad dressings and other foods have more palatable textures.

In most cases, a wild forest of kelp is adopted and cared for by divers, who tend the forest's needs, harvesting the tops of the underwater "trees" and assisting new plants in establishment, treating ill plants and fending off herbivorous predators (and the carnivorous predators who desire to eat the divers).

However, some algae is seeded and grown on trellises in sheltered bays, and harvested by hauling in the trellises and disentangling the algae from it.

Whether seeded on ropes or brought under forest management, though there are no roots to feed, the hygienic principles of Tullian rows and aisles still applies. Good circulation of seawater, which the algae eat from, allows improved yields. The elimination of wastes from the growing area helps control the organisms that would eat the algae. Though tillage is not undertaken per se, a kind of stirring (like is undertaken with blue-green algae) is undertaken by the ocean's tides, and facilitating the movement of these tides, controlling access to sunlight and otherwise and the farmer finds improved yields when they help the algae eat and eliminate wastes, and help to shelter the algae and defend it.

The Fisheries and Aquaculture Department of the United Nations Food and Agriculture Organization in *BIOLOGY AND ECOLOGY OF LAMINARIA* (http://www.fao.org/docrep/field/003/ab724e/AB724E01.htm) discusses the cultivation of one variety of Kelp (Laminaria) native to the sea of Japan. Like all kelps, Laminaria has 15 stages to its complicated life cycle. The UNFAO provides an illustration (originally by C. K. Tseung, 1987): 1: zoospore 2: embryospore 3: germination of embryospore 4: newly formed gametophyte 5a: female gametophyte 6a: male gametophyte 6a: mature oogonium 6b: spermatozoid being discharged from antheridium 7: discharged egg attached to oogonium 8: motile biflagellate spermatozoid 9: fertilization 10: zygote 11: 7-celled seeding or sporeling (sporophyte) 12: young seedling or sporeling 13: young sporophyte 14: robust sporophyte 15: mature sporophyte with sporangial sori



The kelp's complicated reproduction is described by the UNFAO: "the asexual sporophyte generation (2N) produces motile zoospores (N) which develop into male and female gametophytes. Whereas the sexual gametophyte generation (N) produces male and female gametes (N). The male gametophyte plant produces male gametes called spermatozoids or antherozoids. The female gametophyte plant produces female gametes (eggs). At fertilization male and female gametes fuse to form the zygote (2N) which subsequently develops into a young sporeling at the beginning the sporophyte generation. Zoospores are produced on the fronds of mature sporophyte plants in sporangial sori ("spore sacs", plu. sporangia, sing. sporangium). Sporangial sori are cup-like structures where cells divide through meiosis to produce haploid (N) male and female zoospores. The pelagic zoospores are motile, having two flagella. When released from the sporangial sori they

drift and swim around in the water for 5–10 minutes at 15–20° C and up to 48 hours at 5° C, then settle and adhere to the substratum where they develop into male and female gametophytes."

Luckily, this is largely unnecessary for practical kelp production. It suffices to say that the seaweed responds to changes in sea temperature and other seasonal stimulus to time its lifecycle events. With a variety of kelp adapted to nearly every stretch of coast, it is possible to harvest spores from wild kelp for domestication that will likely be adapted to the conditions of the ocean where the kelp forest will be tended.

The spores are typically harvested and grown out in land based tanks for transplanting. When they are ready to transplant, they are hung from ropes at appropriate depths and allowed to grow until maturity (different varieties mature at different rates). Transplanting improves harvest because the young kelp don't have to compete with so many other species (or members of their species) in their early months.

Mariculture and aquaculture plant production: wild rice – an annual amphibious plant

In Mariculture and Aquaculture, the plant functions much as a land plant, but is better able to extract and release chemicals dissolved in the water through structures on leaves and stems. Most plants in water are microscopic, as size is a disadvantage to extracting dissolved chemicals.

Few plants are grown outdoors in mariculture and aquaculture, though breeding is being undertaken to allow common grains to be grown in tidal and ocean environments.

Three significant crops are grown outdoors in America: wild rice is grown in fresh water and the cranberry is grown in salt. The first demonstrates the struggle of an emerging aquatic farming industry, the second signals the early victories of the struggle. True rice is also grown in fresh water, and demonstrates the potential of domesticating aqueous plants.

Ervin A. Oelke in his *Wild Rice: Domestication of a Native North American Genus* (p. 235-243. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York) describes the domestication of wild rice to have begun in 1950:

Growing wild rice as a field crop was first attempted near Merrifield, Minnesota in 1950-1952 (Oelke et al. 1984). James and Gerald Godward diked a 0.5 ha area, planted it with seed collected from a nearby lake, and flooded the field. The field was drained before harvest and the crop was harvested by hand. An additional 16 ha were planted by them in 1953 and harvested with a small pull-type combine. They had good crops the first few years, but leaf blight (Bipolaris oryzae B. de Haan) caused serious losses thereafter. However, they continued their pioneering efforts, and today one of their sons has nearly 1,000 acres in wild rice production.

Initially, the only seed available for planting in fields was of shattering types found in natural stands. These early fields were harvested several times over a 2-to 3-week grain-ripening period with specially designed, multiple-pass harvesters (Fig. 5). In 1963, Dr. Paul Yagyu and Mr. Erwin Brooks with the University of Minnesota, Department of Agronomy and Plant Genetics, discovered plants in a grower's field that retained their seed longer than the rest of the plants (Oelke et al. 1984). From these few plants, they and other breeders developed cultivars with more resistance to shattering than types growing in lakes and rivers. Today, most of the wild rice being grown in fields are more shattering resistant. Yields of unprocessed grain from shattering types grown in fields typically ranged from 168 to 224 kg/ha, whereas, with shattering resistant cultivars, yields have been reported as high as 1,680 kg/ha in Minnesota and twice that amount in California.

The development of more shattering resistant cultivars of wild rice was largely responsible for a tremendous expansion in field production that occurred in the late 1960s and early 1970s. Practically all the expansion at that time was taking place in Minnesota where area increased from 354 ha in 1968 to 7,090 ha in 1973 (Oelke et al. 1982). The finding of improved shattering resistance was the development that eventually made possible the shift to more efficient harvest with grain combines (Fig. 6). The improved harvest efficiency from the use of combines, together with greater harvested yields from shattering resistant cultivars, were major contributing factors to expanded field production at that time.

Other factors that were important in the development of wild rice as a field crop were: the contracting of production by Uncle Bens, Inc., and the formation of Manomin Development Corporation for development of seed, growing, and marketing of wild rice in 1967; the formation of a Wild Rice Growers Association and the initiation of a research program on processing at the University of Wisconsin-Madison in 1970; and the initiation of a research program at the University of Minnesota on breeding, production, diseases, insects, soil fertility, machinery, and processing in 1972. In 1974, a Minnesota Paddy and Wild Rice Research and Promotion Council was formed after growers voted to contribute a specified fee for each pound of processed grain produced for promotion and research of the crop. In the early 1970s, growing wild rice as a field crop began in California and by 1987, the added production had a significant impact on supply and price. In 1982, an International Wild Rice Association was formed which now includes all producers, processors and marketers in the United States and Canada.

Marketing and processing of wild rice was significantly aided by the formation of two cooperatives in Minnesota (Winchell and Dahl 1984). In 1971, the first successful cooperative was United Wild Rice, Inc. (United). They constructed facilities and staffed the program with a professional manager and sales force. A second cooperative, Minnesota Wild Rice Growers (MRG) was formed in 1974. In 1983, a third cooperative was organized under the name of the Independent Wild Rice Producers Association. Later in 1987, a marketing and product development company, New Frontier Foods, Inc. was formed by some growers. In 1986, Busch Agricultural Resources purchased the processing facilities and marketing operations from United Wild Rice thus involving another large marketer in the industry. The marketing of the cultivated crop was significantly aided by the long-time harvest and marketing of the grain from natural stands. The name of the product was already established in the gourmet markets, thus the cultivated crop could exploit the gourmet nature of the grain.

Even though wild rice is grown now on hectarage in several states it is continuing to undergo domestication in that wild rice still possesses several traits of a wild species such as some seed shattering, seed dormancy, tiller asynchrony, and variable seed size (Hayes et al. 1989). However, these traits are under genetic control and given the heritability of these traits, deliberate selection should accelerate the domestication process.

Since about 1950, wild rice has been in the process of becoming a domesticated crop in the United States and is now being grown commercially in both the United States and Canada (Oelke et al. 1982; Stevenson 1988). Prior to that time, natural stands were the only source of the grain, and supplies were limited and varied greatly from year to year. With the advent and growth of commercial production, supplies of wild rice have increased tremendously over the last 25 years. Natural stands continue to be harvested, but the proportion of total supplies derived from natural stands has steadily declined. In some areas, including the entire state of Minnesota, natural stands of wild rice, by law, must be harvested only by traditional canoe-and-flail method, whereas in some parts of Canada, mechanized harvest is permitted.

Of all the wild rice harvested by hand, Minnesota is likely to account for more than half in any given year.

In Canada, commercial production of wild rice takes place predominantly in lakes leased from the various provincial governments (Winchell and Dahl 1984). Lease provisions vary by province, but generally lease holders are

permitted to seed the lakes and, in some cases, to control water levels, and are granted exclusive harvesting rights. Much of the wild rice acreage in these leased lakes is harvested with the use of airboats (Stevenson 1988).

In the United States, wild rice is being produced commercially as a 'domesticated' field crop in diked, flooded fields. Minnesota and California account for most of the hectarage (8,000 and 4,000 ha, respectively, in 1992) with additional amounts in Idaho, Wisconsin, and Oregon.

The cultivation is similar to rice, which wild rice is not even distantly related to.

The crop is grown similarly to rice (Oryza), thus relatively flat areas are needed where a flood can be maintained for most of the season. It will grow well on organic or inorganic soils if the proper nutrients are applied. Since the plant is relatively tall, its nitrogen requirements are lower than for rice. In addition, it will grow well in cooler and deeper water than rice, thus requiring fewer weed control chemicals compared to rice.

Wild rice seed needs to be stored for 90 days in cold (3°C) water before dormancy is released. Seed storage is an added cost in the Sacramento Valley of California compared to Minnesota. Wild rice seed loses viability, especially after dormancy release, when it is allowed to dry below 25% moisture content. Dormant seed, however, can withstand drying below 25% moisture but needs to be stored in cold (3°C) water for 90 days to release dormancy (Oelke and McClellan 1992). In contrast to rice seed, wild rice seed when planted 5 to 8 cm into the soil before flooding can still grow while rice seed cannot when covered for more than a few days by both soil and water. In Minnesota, new fields are seeded with 45 kg/ha of seed (35% moisture) while in California a seeding rate of 112 kg/ha is common. A higher seeding rate is used in California because plants don't tiller as much as in Minnesota and also a higher plant population can be utilized since no leaf diseases are prevalent.

In Minnesota and Wisconsin fields are prepared, fertilized, and seeded in the fall and flooded to a depth of about 30 cm in the spring. In California, these operations are done in the spring except in some of the higher elevations where production practices are similar to those in Minnesota.

In Minnesota, once a field is seeded to wild rice it will reseed itself due to seed shattering even when planted to cultivars with some shattering resistance. Thus, fields are generally kept in production for 3 to 4 years. It is also difficult to change a field to a new cultivar due to seed dormancy, causing volunteers the following year. Cultivars without seed dormancy are needed to allow more rapid adoption of new, improved cultivars. The plant density the second and following years is also too high making it necessary to reduce the plant population by airboats equipped with a series of V-shaped knives set 15 to 20 cm apart on a toolbar attached to the rear of the boat. The boat travels at a speed of 55 km/h with the knives riding on the soil surface, and removing about 70% of the plants. The plant density desired is 40 plants/m2.

In Minnesota and California, fields are drained about 3 weeks before harvest with combines. Combines are often adapted with half or full tracks for ease of harvesting in moist soils. The grain is harvested at 30% moisture since seed shattering occurs if allowed to dry more on the plant. The moist grain is immediately transported to processing plants and not dried or stored on the farm like other cereals. At the processing plant the grain is cured, parched, hulled, and graded.

Wild rice is well adapted to northern latitudes. It is not very productive in the southern United States since warm temperatures accelerate plant growth, and as a result, plant heights are shorter with an accompanying lower number of florets (Oelke et al. 1980). Also the high humidity may result in severe leaf diseases (brown spot, Bipolaris sp.). Wild rice grows well in the warmer climate of northern California, however, cultivars have been developed for that area and the humidity is very low, consequently leaf diseases are not prevalent. Presently, no resistance to brown spot

exists, however variability is present in wild rice germplasm for many other characteristics so that further breeding could permit this crop to be grown in new areas in the future.

The development of amphibious tillage equipment will undoubtedly help the mechanization of wild rice, but oxen and plows have been successfully used in rice cultivation in Asia for millennia and would have application in America, as well. The Tullian method of planting in beds and aisles would assist this plant because it would aid the roots: unlike algae, which have no roots, tillage helps even aquatic plants.

C&G Enterprises, a farm that raises wild rice in Minnesota is very proud of its product and their place in history as one of the first farms to grow this important grain. They discuss the process of their farming on their website, http://www.mnwildrice.com/riceinfo.htm.

Wild Rice, Minnesota's State Grain, is almost as old as history itself. This highly nutritious grain is not actually rice, but an annual water-grass seed, zizania aquatica. Naturally abundant in the cold rivers and lakes of Minnesota and Canada, wild rice was the staple in the diet of the Chippewa and Sioux Indians, native to this region.

Even today, the wild rice grown on Minnesota state waters is regulated and must be harvested in the traditional indian way. That means one must first purchase a license, then harvest wild rice during state regulated seasons. The rice must be harvested from a canoe, utilizing only a pole for power and two rice beater sticks as flails to knock the mature seeds into the bottom of the boat.

Enter the commercially produced wild rice. As far back as 1962, Minnesota farmers have tried to tame the 'wild' rice. Taming proved more difficult than imagined and almost a quarter of a century later 'corralled' would be more appropriate than 'tamed' to describe the advances made toward commercialization.

The wild rice plant has received some very special instructions from nature on how to grow, mature and repopulate itself. First a deepwater environment is necessary, requiring commercial wild rice producers to develop good permanent field dikes, similar to those required in cranberry production.

Since wild rice grows in cold weather country, it must have a lot of energy in the spring to germinate from the bottom of a lake or stream. Thus a seed with very high protein has resulted. Naturally, the migrating flocks of ducks and geese moving through this region from their northern canadian breeding grounds found a great energy supply from the wild rice seed. This factor and the unpredictable first severe frost of the fall develops a signal that tells the wild rice plant to try to avoid the seed loss. To accomplish this, the seed panicle produces seeds that mature at different times, some early to miss the frost, some late to miss the migrating birds.

Another item of concern is shattering. When the seeds matures it shatters during the slightest wind and falls immediately to the ground. This uneven maturity and shattering makes it very difficult for a farmer to harvest the crop once it has been raised. The wild rice plant has some very distinct growth stages and very unique environmental conditions as well.

First, environment. Since it is an aquatic grass, water is its environment, and proper water depth is important. If too deep, the weak sun rays of spring are diverted from the seed, if too shallow, the plant develops a weak stem. Most important, is consistent water depth. When the seed germinates in the Spring, a tiny hair root anchors the seed in place and the stalk starts to grow to the water surface, picking up air to float itself. When the plant reaches the surface, it joins and forms the float leaf, or banner leaf stage. The long leaves form, floating on the surface of the water at 90 degree angles to the stalk. This is a critical stage for the wild rice plant. Should the water level rise, the stalk is pulled up since it is very weakly rooted. Should the water level drop, the weak stalk can collapse. Also, during this stage, high winds can create large waves that will tear up a wild rice stand.

Should conditions be just right, the leaves produce plant food, the stalk and root system strengthen and create a good strong base to support more vegetative growth of the plant. With this strong base, the strong plant goes aerial, that is, it stands up. the floating leaves rise above the water, spread out to the sun and maturity takes its course. Under good conditions, an overabundance of plants reach this stage and overcrowding occurs, killing many plants, stunting the growth if others. Commercial producers have found that thinning allows the surviving plants to grow larger and stronger. Airboats have been developed with cultivator tools to effectively thin the rice beds.

The month of august is a real test for the maturing wild rice plant. High summertime temperatures and very high humidity conditions around the water environment of wild rice create ideal conditions for Helminthosporium disease development. This and other blight conditions can wipe out a weak overcrowded stand in a matter of days.

As harvest approaches, producers try to time their harvest activities to maximize yield. They drain the water from the fields to dry the ground so that special, high flotation combines can operate in the boggy soils.

September, the usual harvest time for wild rice, is accompanied by unstable north country weather. Now that the water is drained from the fields, the heat reservoir provided by the water is gone and so is the small degree of frost protection the water afforded the wild rice. Should a frost occur now, the crop is lost.

As mentioned earlier, wild rice shatters easily with the wind and a small storm can ruin a farmer's entire crop in minutes.

If the producer survives these many factors, and obtains a successful harvest, his yield is still very meager. Traditional white rice farmers realize a yield of 4,000 to 6,000 pounds per acre. While with virtually the same investment in land, equipment and time, the wild rice producer can sometimes realize only 100-200 pounds per acre.

Now that the crop is in, another very unique process of curing and packing begins. The Indians had found wild rice to store indefinitely if the seeds were parched in the fire. Today, we still follow the same process, only in much more samitary conditions and in greater volumes.

Wild Rice is harvested green, and placed in long narrow rows about 10 inches in depth in a curing yard. While the wild rice is in the curing rows, the chlorophyll dissipates from the plant. To prevent damage to the seed, the process involves turning constantly, and adding water to closely approximate its natural watery repository.

From the curing yard the browned rice kernel with its seed hull intact goes to the parchers where the moisture is dried out. During this process, the starches gelatinize and the characteristic roasted nutty flavor is developed.

From the parchers, the rice is hulled, removing the fibrous hull, exposing only the shiny black wild rice seed. The wild rice is then graded to as many as 49 grades and transported immediately to a storage facility. Here all rice is catalogued in, checked for cooktimes and warehoused for the producers.

We see the influence of cranberry culture on wild rice cultivation, and also the opportunity for the introduction of tillage and other advanced cultivation techniques, pulled by the floating tractors. We see the need for breeding (as evidenced by the low yield of wild rice and the high yield of rice).

Oelke notices the nutritious quality of the rice matches its excellent flavor, and this is reason to believe it will continue to be demanded: "This grain has a high protein and carbohydrate content, and is very low in fat (Anderson 1976). The nutritional quality of wild rice appears to equal or surpass that of other cereals. Lysine and methionine comprise a higher percentage of the amino acids in the protein than in most other cereals. The SLTM value (sum of lysine, threonine, and methionine contents) often serve as a measure of the nutritional quality of cereals, and is a little higher for wild rice than for oat groats, which is one of the better cereals for humans. Amino acid composition of processed and unprocessed wild rice is similar, which indicates little reduction in nutritional quality during processing. Wild rice contains less than 1% fat, of which linolenic and linoleic acids together

comprise a larger proportion of the fatty acids (68%) than in wheat, rice, or oats. Although these two fatty acids are easily oxidized and make wild rice prone to develop rancid odors, the high levels of linolenic acid make the fat in wild rice highly nutritious. Mineral content of wild rice, which is high in potassium and phosphorus, compares favorably with wheat, oats, and corn. Processed wild rice contains no vitamin A, but serves as an excellent source of the B vitamins: thiamine, riboflavin, and niacin."

Mariculture and aquaculture plant production: cranberries – perennial amphibious plants

The entirely nearly aquatic nature of wild rice compares neatly with the nearly terrestrial nature of cranberries, and the annual wild rice, though amphibious, does not require the same treatments as the perennial amphibious cranberry. Perennial amphibious plants require an emulation of natural sedimentation cycles: water, in all its forms and places, by the grace of the moon and seasons, has tides and sedimentation cycles.

Cranberries are a group of evergreen dwarf shrubs or trailing vines in the genus Vaccinium subgenus Oxycoccos, or in some treatments, in the distinct genus Oxycoccos. Cranberries are low, creeping shrubs or vines about 4 to 5 feet long and about a foot tall. They have slender, wiry stems that are not thickly woody and have small evergreen leaves. The flowers are dark pink, with very distinct reflexed petals, leaving the style and stamens fully exposed and pointing forward. They are pollinated by domestic honey bees. The fruit is an epigynous berry that is larger than the leaves of the plant; it is initially white, but turns a deep red when fully ripe. It is edible, with an acidic taste that can overwhelm its sweetness.

Historically, cranberry beds were constructed in wetlands. But now, techniques from aquaculture have been introduced to field production and typically modern cranberry beds are constructed in upland areas that have a shallow water table. The topsoil is scraped off to form dikes around the bed perimeter. Drainage systems are installed and clean sand is hauled in to a depth of four to eight inches. The surface is leveled flat to provide even drainage. In addition to making it possible to hold water, the dikes are constructed to allow equipment to service the beds without driving on the vines. Irrigation equipment is installed in the bed to provide irrigation for vine growth and for spring and autumn frost protection.

Cranberry vines are propagated by moving vines from an established bed. The vines are spread on the surface of the sand of the new bed and pushed into the sand with a blunt disk. The vines are watered frequently during the first few weeks until roots form and new shoots grow.

To harvest cranberries, the beds are flooded with six to eight inches of water above the vines. A harvester is driven through the beds to remove the fruit from the vines. For the past 50 years, water reel type harvesters have been used that beat the cranberry bushes to release the berries, which then float on the water and are corralled into a corner of the bed, where they are pumped out. Although most cranberries are wet-picked, some are dry-picked. But the higher labor costs and lower yield, damage to the vines and the higher rate of fruit bruising and other disadvantages make dry picking unpreferrable.

Because the bushes are so low-growing, weeds are typically mowed to allow light in, and more fertilizer is added to compensate the loss to the weeds. When the bushes grow long enough, they are covered with a fresh layer of sand, and this not only suppresses the weeds but also helps keep the cranberries more fit: it emulates the natural sedimentation of a river or lake! The wandering nature of the vines makes hoeing rows very difficult. The cranberry has only recently

been domesticated in the United States (since about the mid-19th Century) and much work is to be had in breeding a better cranberry! It is not surprising that cranberries are also susceptible to insect damage and many soil-borne diseases, too. Until these advances are made, growers have to emulate natural sedimentation cycles.

True rice is, of course, the most popular food grown amphibiously, and its cultivation is very similar to that of wild rice. There are varieties that are more terrestrial, and varieties that are more aquatic, but, unlike the microorganisms, growing plants in aquaculture and mariculture will require some degree of amphibious terrain, and if the plant is perennial, attention should be made to retain (as closely as possible) the natural sedimentation cycles of the natural bodies of water from which the plant was domesticated.

Hydroponics and aeroponics are kinds of aquaculture and mariculture and plant production by these methods easily integrate with animal production

Hydroponics and aeroponics are a kind of aquaculture and mariculture that most recently developed.

Recently, plants have been cultivated in water and gravel, and even suspended mid-air and grown in mist. The light for these plants is usually artificial and comes from various kinds of electric light bulbs and lasers. In some cases, extraordinary total production may occur in these systems, and when artificial heat is introduced, growth may continue year-round without interruption.

The extraordinary cost of these growing methods makes it prohibitive to wider use. They are typically employed for crops which must, for legal reasons, be hidden from sight, or are otherwise illegal and earn a high enough price to justify the hydroponic and aeroponic system.

In Colorado, after marijuana was legalized, the marijuana farmers who were growing marijuana with hydroponic and aeroponic systems continued to grow their marijuana with hydroponic and aeroponic systems: the high price and great demand for the drug justified the practice. In Mexico (where marijuana is legal) and in much of the United States, however, many farmers grew and continue to grow the crop outdoors at a comparable cost: what the outdoor farmers do not spend in equipment, they must spend in security and risk: these fields are often found and destroyed, if not by law enforcement agencies, than by competitors.

Both aeroponics and hydroponics have been tested for use in extraterrestrial colonies, and hydroponic production is often used to compliment aquaculture and mariculture: the plants and animals act symbiotically to keep the environment hygienic for both kingdoms.

The gravel in hydroponics acts as a kind of soil to anchor the plant, and the nutrients are provided in suspension in the water, which also keeps the plant hydrated. In both methods, the danger is present that the plant will suffocate, being unable to breathe through its roots. However, periodically drying the roots through timed water pumps reduces this risk. A great risk is present that fungus will infect the plants, and this is usually compensated by antifungal agents – or the simultaneous cultivation of water animals.

Shrimps, lobsters, oysters, crabs, abalones, and various other crustaceans, mollusks (both aquatic and terrestrial), and fishes are commonly paired with plants. In aquaculture, the water is pumped through the animals' aquariums and then through the plants' terrariums. In mariculture, they are grown in the same fenced off habitat, paired in a way that the animals do not eat the plants, but rely on them for shelter or ignore them completely.

Deep sea fish production

A recent innovation that requires only primitive technologies is deep sea fish production. The technology and technique was invented by Ocean Farm Technologies of Searsmont, Maine. Founded in 2005, OFT won the American Council of Engineering Companies National Engineering Excellence competition for their Aquapod fish containment system in 2007, and is continuing to position itself at the forefront of maricultural technology.

Though not five years old yet, OFT has developed the Aquapod technology required to farm the deep ocean. But now they are entering into the brave new market of ocean electrical and mechanical energy generation.

Aquapods are geodesic spheroids designed to pen fish, both to protect them against predators and to allow for agricultural practices. Whereas usually such fences are constructed in bays, rivers and atolls, the aquapod encloses a spherical space for open ocean farming.

Aquapod net pens of various sizes are currently deployed in Puerto Rico, Panama, South Korea, Mexico, New Hampshire, Massachusetts and Maine. For these Aquapods they are developing additional technologies for feeding, cultivating, transferring and harvesting fish in open ocean systems.

In 2009, two newly improved Aquapens were installed off South Korea for Okwang Fisheries Union and Sonora, Mexico for Pesquera Delly. The recently deployed Aquapods each have a volume of 3,625 cubic meters (957,000 gallons) and a diameter of 20 meters (64 feet).

Installed in waters about 200 feet deep, they are allowing their companies to produce high quality fish that are difficult or impossible to obtain in the wild.

Both new buyers represent a standard customer: having undertaken traditional fishing, they are turning to Aquapods to not only improve the quantity of fish sold, but the quality.

Currently cobia, a high quality warm water fish destined to be a favorite in the seafood market, are being harvested from the installation at Snapperfarm, a pioneering offshore deep-water fish farm based on the Puerto Rican island of Culebra.

OFT's customers "represent a growing number of successful fishing companies that are actively pursuing sustainable open ocean aquaculture as the solution to the declining supply of wild fish and a steadily increasing demand for seafood," explains OFT. "Okwang will raise Pacific cod in the deep, cold waters off Korea, while Pesquera Delly is pioneering shrimp culture in the Sea of Cortez. These companies represent the forefront of marine aquaculture development in their countries."

Both companies are expected to expand production—and purchases—of Aquapods quickly. Pesquera Delly has already placed an order for two more Aquapods which will be delivered to Mexico later this summer. OFT expects that high value species like Cobia, grouper, moi, bream, amberjack, pompano cod, halibut, haddock and sablefish will become standard breeds in these new farms.

There are many reasons to go deeper. Deeper waters have strong and consistent currents that can both reduce environmental impacts while simultaneously optimizing growing conditions. And there is much less regulation to get in the way of business!

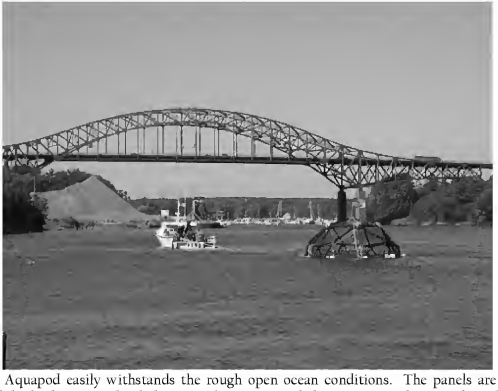
Open sea farms have the advantages of avoiding low or high water temperature conditions as necessary, reduced waste nutrient impact, isolation from other farms (lower disease or parasite transmission) and less conflict with near shore recreational users and onshore land owners. The UN Food and Agriculture Organization reports that Aquaculture must double in 20 years to meet global

demand because shortfall by 2025 from existing sources is amounting to tens of millions of metric tons. This is good news for OFT, which understand 1 million metric tons of fish to be $1.5 billion in new net pens because most of this expansion will have to be off shore, in deep water: with Aquapods, regions previously excluded from marine fish farming due to lack of protected near shore sites will be able to use their deep sea waters.

OFT is helping this expansion with remote monitoring and feeding operations.



Above: An Aquapod can be built on site, or lifted by crane onto a transport boat, or into the water to be towed. Picture from OFT. Below: An Aquapod under tow. The Aquapods can be moved if desired very easily. This presents many advantages. If local conditions don't suit the needs of the farmer or the fish, if laws change, if hazards present themselves, the Aquapod can be towed easily to a new location. Picture from OFT.



The Aquapod easily withstands the rough open ocean conditions. The panels are made of reinforced high density polyethylene (with 80% recycled content) and covered with coated galvanized steel wire mesh netting. The Aquapod can be easily submerged or surfaced during

normal operations, or to better protect it during storms, or for collision safety. The pods can be towed as needed, even while in operation. They are available in sizes from 115 cubic meters (8 m diameter) to 11,000 cubic meters (28 m diameter).

The Aquapod improves on traditional maricultural technologies considerably. Individual net panels or groups of panels are modified to accommodate other functions, such as access, feeding, fish transfer, grading, and harvesting. "Net handling activities in present commercially sized fish pens are labor-intensive, require significant power and cannot be performed in strong seas and currents. The modular nature of the Aquapod solves this problem by utilizing individual net panels which are interchangeable and scaled to be handled easily either on the surface or while submerged," OFT explains in their product description. And the tensioned vinyl coated galvanized steel wire mesh for containment netting is more predator proof, and better contains the fish, resulting in less escapement. Aquapod frames have a life expectancy of 40 years, though the mesh has a life expectancy of 10 years.



Aquapods can be made to rise above the water for servicing, but are usually deployed under water to allow the space to be filled entirely with water. Picture from OFT.

To feed the fish, one or more panels is modified to receive and distribute hydraulically supplied feed from a centralized feed barge or boat. Feed pipe installations are easily fixed to the pen at any location on the exterior.

Because the Aquapod can be orientated easily, there is no need for divers to undertake cleaning and maintenance of the structure, leading to improved worksite safety.

OFT will install their system anywhere that is needed, whether launched from a dock or a beach. They provide ongoing support to customers regarding feeding systems, installation of

nursery nets, species specific habitat, cleaning, harvesting, and environmental monitoring systems for their Aquapod net pens. OFT has also dedicated itself to the development of wave energy converters, with the support of a Small Business Innovation Research (SBIR) grant from NOAA. Partnering with OFT in the project is Resolute Marine Energy, Inc. (RME) of Watertown, MA and the Massachusetts Institute of Technology in Cambridge, MA.

The goal of this project is to demonstrate the feasibility of the device for its initial application, which is providing compressed air for use in operating offshore fish farms. "The system has two parts; a discus-shaped buoy that rises and falls with the waves and a submerged cylindrical housing that remains relatively stable. The buoy is 54 inches in diameter and is topped by a navigation light and an antenna for communications to shore. The submerged housing is a slender 23-foot-tall cylinder with an enlarged portion towards its base, where the drive mechanism, compressor, air storage tanks, and electronics are housed. The housing also has an eight-foot diameter damper plate for added stability. The two components are connected by a hollow rod that reciprocates in and out of the housing through a watertight seal," explains OFT. The basic design is an adaptation of offshore power systems. Such systems generate electricity, and the ingenuity of transforming wave force into air compression not only meets the needs of offshore aquaculture for air to control the buoyancy and position of submerged fish cages, but at the same time presents potential improved electrical generation system solutions.

It is easy to hope the best for such a company, but it is easier still to hope for the betterment of humanity through their efforts. By developing the platform and sphere (so to speak) upon which deep sea industry may begin to sustainably develop, OFT has bridged the previously impossible technological gap that prohibited the development of this last Earthly frontier.

As is already been seen, industrial fishing has led to industrial power generation, and the economics of the industry will gradually require the development of fish food production and permanent settlement upon the ocean—and the subsequent technologies required for such a fishing colony to be successful.

OFT will one day be remembered for their Daniel Boone-like pioneering role in the opening of the sea and their Squanto-like service of agricultural education.

How magnificent it must have been to have witnessed the first functional fence installed on a terrestrial farm by the now-unknown company of inventors! How fortunate we are today to watch and learn from this modern inventive company.

Hazards of pollution in fresh and salt waters requires aid of marginal marshes, corals and bottom life; provide reservations for wildlife: balanced, diverse and dense ecosystems are as important for aquaculture and mariculture as for any terrestrial agriculture

While the terrestrial farmer has little trouble tilling the soil to encourage the microorganisms that will purify their land from the toxic pollution that would taint their produce or prevent their agriculture by killing domestic organisms, those who undertake aquatic agriculture have few options for purification. Heavy metals, radioactivity, pharmaceuticals, biological agents, and even run-off fertilizers, herbicides and pesticides from terrestrial farms are only the beginnings of what aquatic farms must consider. The best advice is to encourage marshes, corals, bottom life and as much life as possible in the marginal areas of the bay, lake, river, or ocean in which agriculture is taking place: in these ecosystems, there are the microorganisms that can best sequester and detoxify the poisons that threaten aquatic agriculture.

Do provide reservations for wildlife. Balanced, diverse and dense ecosystems are as important for aquaculture and mariculture as for any terrestrial agriculture.

Pearl and other jewelry production

Another important aquacultural and maricultural production is that of jewelry. Besides shells, farmers can also produce pearls by farming.

A pearl is produced within the mantle of a living shelled mollusk. Just like the shell of a mollusk, a pearl is made up of calcium carbonate in minute crystalline form, which has been deposited in concentric layers. The ideal pearl is perfectly round and smooth, but many other shapes of pearls (baroque pearls) occur. The finest quality natural pearls have been highly valued as gemstones and objects of beauty since the beginning of time.

Very few wild pearls are harvested anymore. Farmed pearls from pearl oysters are typical. Pearls from the sea are valued more highly than freshwater pearls. Besides use in ornamentation, pearls have also been crushed and used in cosmetics, medicines, or in paint formulations.

Pearls that are considered to be of gemstone quality are almost always nacreous and iridescent, like the interior of the shell that produces them. While almost all species of shelled mollusks are capable of producing pearls of more or less shine and spherical shape, oysters are typically used to produce the best pearls.

When an irritating microscopic object becomes trapped within the mollusk's mantle folds, a pearl is "seeded." Nacreous pearls, the best-known and most commercially-significant pearls, are primarily produced by two groups of molluscan bivalves or clams. A nacreous pearl is made from layers of nacre, by the same living process as is used in the secretion of the mother of pearl which lines the shell.

The unique luster of pearls depends upon the reflection, refraction, and diffraction of light from the translucent layers. The thinner and more numerous the layers in the pearl, the finer the luster. The iridescence that pearls display is caused by the overlapping of successive layers, which breaks up light falling on the surface. In addition, pearls (especially cultured freshwater pearls) can be dyed yellow, green, blue, brown, pink, purple, or black.

In the wild, many hundreds of pearl oysters or pearl mussels have to be gathered and opened, and thus killed, in order to find even one wild pearl, and for many centuries that was the only way pearls were obtained. This was the main reason why pearls fetched such extraordinary prices in the past. Now, an irritant is inserted into the young mollusk to ensure that when it is harvested, it is likely to have a pearl.

Typically, this irritant is a tissue implant. A tiny piece of mantle tissue of a donor shell is transplanted into a recipient shell. This graft will form a pearl sac and the tissue will precipitate calcium carbonate into this pocket. There are a number of options to produce cultured pearls: use freshwater or seawater shells, transplant the graft into the mantle or into the gonad, add a spherical bead or do it non-beaded.

The UNFAO provides instruction on farming pearls in their *Pearl Oyster Farming and Pearl Culture* training manual (prepared for the Pearl Oyster Farming and Pearl Culture Training Course conducted by the Central Marine Fisheries Research Institute at Tuticorin, India and organized by the Regional Seafarming Development and Demonstration Project in 1991). However, one major lesson to be learned from the FAO is to examine the local conditions of the water the mollusks are going to be raised in to understand better what species of mollusk to use, and its ideal growing

conditions. Typically, pearls are not grown indoors, though it would be possible to do so. The body of water should be a moving one, if not by tides than by currents.

If the attempt to culture oysters or mussels indoors is made, favor oysters: oysters produce superior pearls. You will require if not your own breeding facilities, than access to a commercial breeder. The FAO explains that "oyster broodstock are maintained at a water temperature ranging from 25–28 °C in a controlled room. They are fed with a mixed algal diet at a ratio of 4 l per oyster/day. The algal food is supplemented by raw corn flour at 30 mg per oyster/day. Pearl oysters with maturing gonad fed with the above food for 45 days will spawn with a 30 % response. The matured oysters can be kept for a prolonged period at 25–28 °C, while spawning of these oysters can be stimulated by raising the water temperature by few degrees. Spawning of natural oysters with mature gonads occurs when there is a simple change in the seawater environment or a mechanical shock by shell cleaning or a change in water pressure. In all cases males spawn first (Plate II B) and this induces the females to spawn within 30 minutes. In the absence of natural spawning the technique of induce spawning is employed. In this technique thermal stimulation is adopted predominantly by gradually increasing the water temperature by several degrees (from 28.5 °C to 35.0 °C). Spawning of pearl oysters can also be effected by chemical stimulation. Different concentrations (1.532, 3.064 and 6.128 millimolars) of hydrogen peroxide in combination either with normal seawater or alkaline seawater (pH 9.1) is used in inducing spawning. Different pH media (8.5, 9.0, 9.5 and 10.0) are prepared either using Tris buffer or Sodium hydroxide pellets (NaOH) and the pearl oysters are induced to spawn. A pH value of 9.0 in the case of Tris buffer and 9.5 in NaOH gives 78.6 % and 68.4 % of spawning, respectively. Injection of 0.2 ml of N/10 ammonium hydroxide (NH_4OH) solution into the adductor muscle of the pearl oyster results in 48 % spawning. Fertilization takes place externally in the water medium. Following fertilization, the pyriform eggs assume a spherical shape with the breakdown of the germinal vesicle (Plate II D). During fertilization the polar body appears and persists on the embryo up to blastula stage."

For their tank, the farmer should emulate their natural conditions. The FAO identifies ideal open conditions: "gravelly bottoms are suitable for pearl oyster farming, while sandy or muddy bottoms should be avoided. Oyster growth is affected by water temperature and nutritional condition of the ground. Repeated culture on the same ground leads to some extent the deterioration of pearl quality. The chemical and physical state of the sea bottom is affected by the organic substances discharged from the oysters and fouling organisms. Periodic removal of such accumulated substances from the bottom of the culture grounds often increase production as well as quality...Pearl oysters generally prefer clear waters as high turbidity levels will affect their filtration efficiency. A decline in oyster condition was noted at Veppalodai farm due to the high silt content in the farm area throughout most of the year...Culture sites should be naturally sheltered against strong winds and waves. Tidal amplitude and currents must be sufficient in order to allow replenishment of oxygenated water and fresh plankton and flush away waste materials. In strong water currents the formation of the pearl layers is usually fast, but the quality of pearls produced is affected..."

The breeder will then need to care for the young oysters, according to the FAO. "The embryo is ball-like with transparent cells and a blastocoel. The embryos lift themselves in the water column and congregate at the surface. The floating embryos are siphoned out to clean containers and the residues at the bottom, containing broken tissues, undeveloped embroys, unfertilized eggs, sperm, etc. are discarded. Reorientation of cells starts and the blastocoel and blastopore are formed. The blastula stage is reached 5 hours after fertilization."

The development of the young oysters dictates their care: after they are able to feed themselves (about 20 hours after fertilization), they are fed Isochrysis galbana (a microalgae) for about 15 days,

then they are fed a mixture of Chaetoceros and I. galbana in a ratio of 1:1 for another 15 days, at which point they are fed an adult diet. After about 2 months, the young oysters (now in the "spat" stage of life) are then transferred to the farm in velon screen netcages with a mesh size of 400 µm. Mortality may occur if spat measuring less than 3 mm are transplanted. Spat growth is monitored carefully and the netcages are changed whenever necessary. The size of mesh of the rearing cages is also monitored. The oyster spat attain an average size of 40–45 mm in 12 months. It is expected that only 30% of the young oysters will live the first 12 months.

The FAO reports that "although a number of species of pearl oysters have been identified, only a few have been found to produce pearls of good quality and commercial value. Of these, P. maxima, P. margaritifera and P. fucata stand out...[they produce different color pearls]...Pinctada margaritifera (black or steel grey), P. maxima (silvery white), abalones (green) and freshwater mussels (pink). However, in the case of P. fucata, the colour of the pearls produced may be golden yellow, pink, white or cream, depending on slight differences in the site of nuclei implantation. The pearls produced in the ventral region of the gonad are white or golden, while those produced in the dorsal region of the gonad, in proximity to the hepato-pancreas, are usually grey or white. Flawless pearls of regular form are frequently seen among the pearls developed in contact with internal organs, such as liver, byssal gland and intestine. Pearls produced close to the retractor muscle tend to be baroque in shape with irregular protrusions and with a distinct black colouration"

You will need to cultivate phytoplankton for the oysters to eat. The FAO suggests that

Isochrysis galbana is an important algal food for the larvae. Other microalgal cells such as Pavlova, Chromulina and Dicrateria are also suitable for the larvae. The growth and spatfall timing varies with the different algal foods. Chromulina promotes faster growth while Dicrateria gives better spatfall. The flagellates are grown in 4-l Haufkin flasks as stock culture and in 20-l glass carbuoys and 100-l perspex tanks in mass culture. Conway or Walne's medium is used for the culture of these flagellates. They enter the stationery phase of growth in about 15 days in Haufkin flasks and are maintained for two months without aeration. In mass culture, the maximum cell concentration is reached within 5–6 days. The composition of the medium used for mass culture as well as mixed algal culture is as follows:

Potassium nitrate : 0.4 g
Potassium dihydrogen
Orthophosphate : 0.2 g
Sodium silicate : 0.2 g
Sodium EDTA : 0.2 g
Filtered seawater : 30.0 l

The FAO continues...

Like other bivalves, the pearl oyster is a filter feeder. Minute food organisms in the water, enter inside the mantle cavity along with water current passing through the narrow slit formed by the inwardly directed edges of the pallial lobes. These are carried towards the branchiae which act as fine strainers arresting every particle in the water current. The food particles collected thus are carried by the cilia to the crest of the branchial lamellae and from there they are directed by the labial palps into the mouth. The labial palps have the ability to reject unwanted materials like mud particles. Unicellular organisms including infusorians, foraminifers and radiolarians have been found in the stomach of

pearl oyster. Minute embryos and larvae of various organisms, algal filaments, spicules of alcyonarians and sponges were also observed. The presence of diatoms, flagellates, larvae of lamellibranchs, gastropods, heteropods, crustacean nauplii, appendages and frustules of copepods, spicules of sponges and unidentified spores, algal filaments, detritus and sand particles were also noted in the stomachs and intestines of cultured P. fucata collected off the coast of Tuticorin. Oysters from natural beds were also found to contain the same organisms in their stomach and intestine...

The age and growth of pearl oysters in the Gulf of Mannar have been studied in detail. Observations made on cultured pearl oysters collected near Krusadai Island and at Tuticorin show that the oysters can grow to a height of about 35–45 mm at the end of one year, 50–55 mm at the end of the second year, 55–60 mm at the end of the third year, 60–65 mm at the end of the fourth year and 65–70 mm at the end of the fifth year. The weight of the oysters was 10, 30, 45, 60 and 70 g at the end of the first, second, third, fourth and fifth years, respectively. Tracing the growth history of P. fucata produced in the hatchery and grown in the farm at Tuticorin Harbour during 1983 revealed that the species attains a modal size of 47.0 mm at the end of first year, 64.5 mm at the end of the second year and 75.0 mm at the end of the third year. The corresponding weights at ages 1 to 3 years were 8.3, 31.6 and 45.4 g, respectively.

The pearl oysters have been estimated to have a longevity of 5–5.5 years in natural beds, but have been observed to live up to seven years when reared in the farm.

In pearl oysters, the sexes are separate although hermaphrodite conditions have been observed in some individuals. Change of sex takes place in some oyster towards the end of spawning.

Pearl oysters are found from the low tide level to depths of about 75 m, therefore they can adapt and live in varying environmental conditions within this range. Environmental factors such as bottom topography, wind, waves, water movement, current, light, temperature, salinity, dissolved oxygen, pH, nutrient salts, and primary production play a crucial role in the settlement, growth and reproductive pattern of oysters, both in the natural beds and farms. In the Gulf of Mannar, the pearl oysters live on rocky or other hard substrata which lie roughly in a line parallel with and at a distance of 10–16 km from the coast. A rich fauna, comprising members of various groups like sponges, hydroids, polychaetes, lamellibranchs, amphipods, decapods, echinoderms, fishes etc. are usually associated with pearl oyster beds. The oysters obtained from the beds are successfully reared in shallow coastal waters with depths ranging from 4–8 m, where the sea does not become rough. In farming the pearl oysters, the preferred depth of culture is about 10 m where silting should be minimal. Unlike in Japan, the variation in temperature and salinity is not much pronounced in the Gulf of Mannar. The temperature of seawater in the natural beds varies from 27.0 °C (January) to 32.5 °C (May) whereas in the oyster farm at Tuticorin, it fluctuates between 24.0–32.5 °C. Similarly, salinity in the natural beds fluctuates between 27.4 ‰ and 35.90 ‰ with an annual range of 8.5 ‰. The salinity values in the oyster culture site at Veppalodai, ranged between 32.15 ‰ and 33.50 ‰ during 1974–76. An unusual dilution of seawater to 15.69 ‰ for short durations at the Veppalodai farm in November 1977 did not affect the oysters. If salinity level falls below 15 ‰, and if such condition is prolonged, it may lead to mortality. This may happen during unusual heavy rain and heavy discharge of fresh water from rivers in the vicinity. It is well known that the benthic ecology of the pearl culture grounds plays a vital role in the rate of production as well as quality of pearls. Rocky or gravelly bottoms are more suitable. A high amount of silt in the farm water may affect the filtration efficiency of pearl oysters. In Japan it has been observed that some culture grounds yielded pearls of good quality, while others did not. Some grounds yielded pink or white pearls while others produced only yellow and golden pearls. Repeated culture on the same ground sometimes affects the quality of pearls. Areas rich in phytoplankton which is consumed by oyster, are good but there should not be noxious blooms. A mild current of two knots per hour is necessary not only as a source of oxygen-rich seawater, but also to bring in fresh plankton as well as for the removal of metabolic products, and faecal matter. If the water current is strong, the formation of the nacreous layer is faster, but the quality of pearls is inferior. The rich nutrients discharged

by the rivers into the sea increase the productivity of the water. The oysters can also directly remove the organic matter and calcium dissolved in the water. If oyster culture farms are located in places such as the vicinity of a river mouth, which is often exposed to prolonged dilution of seawater due to flooding, oyster growth will be affected.

When grown outdoors, rafts are anchored in the water and oysters are hung in basket cages until they are at a desired depth. But, in some areas with ideal bottom conditions, oysters are raised directly on the water's floor. Young oysters are grown in special cages with mesh or closer bars on the cage. Those who would grow indoors do not have to worry about poor conditions, barnacles, or predators harming their oysters.

No matter if they are grown indoors or out, it is necessary to help the oysters produce a pearl. The FAO gives excellent instructions on this:

The two items needed to induce the formation of a cultured pearl are a piece of mantle and a nucleus. The mantle piece, taken from a donor oyster, is grafted into the gonad of the recipient oyster, along with a spherical shell bead nucleus. The different steps followed in the operation are: (1) selection of oysters, (2) preparation of graft tissue, (3) conditioning of oysters, (4) pearl oyster surgery and (5) post-operation care.

First, the tools required.

Knife: The knife has a blade 9 cm long and a wooden handle 11 cm long. The width of the blade is 1.2 cm at the base and 1.5 cm near the tip. The anterior portion of the blade is slightly curved corresponding to the curve of the oyster shell, so that the blade can be easily inserted between the two shells in closed condition. The blade is made by hand forging and finished by filing and grinding. The knife is used to open the unconditioned oysters by sharply cutting the adductor muscle without touching the mantle lobes.

Scissors: This is a pair of straight surgical scissors of 10 cm length. It is used for cutting a long and narrow strip of mantle from its edge. The cutting edges are sharp and the tips are finely ground so as to enable quick cutting of a strip before the mantle withdraws under the stimulus of contact.

Forceps: The forceps is usually 14 cm long. The two components are filed and ground and are provided with serrations and finely ground points at the tips. The material near the joint is ground to proper size to get required mild tension after due hardness is imparted. It is used to lift the mantle strip from the shell, to hold it while cleaning and trimming and to reverse the strip on the wooden block.

Spatula: The spatula is 17.5 cm long, with a round handle of 13 cm length and 4 mm diameter and a blade 4.5 cm in length and 8 cm in width. The required springiness is given to the blade by grinding and the edges are smoothened out. The spatula is used to remove dirt on the mantle strip and to smoothen the folds on it. It is also used to gently lift back the mantle, labial palps and gills of the oyster during surgery so that the foot and the main body are exposed.

Scalpel: The scalpel is flat and 17 cm long, the length of the blade portion being 3.5 cm. The scalpel is produced by forging from bar stock or blanked from sheet metal and the actual size and shape are obtained by filing and grinding. The instrument is then heat treated to get high hardness. The 2 cm broad cutting edge provided at the end has a delicate curve and is smooth and sharp. The scalpel is used for trimming the mantle strip on both edges, to remove unwanted tissue and to sharply cut the tissue into small bits of the required size. It is also used in place of scissors to cut strips from the mantle.

Oyster stand: The stand is used to hold the oyster in a stable position, so that the operator's hands are free to perform the surgery. It consists of two parts, the base and the clamp. The base consists of a wooden board, to which is

screwed a metal square plate, 4.5 cm wide. A vertical tube of 15 cm in length and 1 cm inner diameter is welded to the basal plate. The tube has a collar at the top provided with a threaded hole for fixing a bolt to hold the shaft of the clamp tightly in position.

The clamp consists of two plates, the head-plate and a movable jaw. The head-plate is mounted on an adjustable tilting head supported by a shaft. The movable jaw is held against the head-plate by a spring. The front edges of the two plates form short, slightly curved lugs, which tend to follow the curve of the oyster shell and prevent lateral movement of the oyster. To the head-plate is fixed a curved rod, which passes through a hole in the shaft. A threaded hole and bolt are provided at this point to fix the rod in position. The plate assembly can be tilted from a vertical to a horizontal position according to the convenience of the operator. For fixing the oyster, the movable jaw is opened by applying finger pressure at the bottom of the plate and after the oyster is placed in position the pressure is released. The jaw holds the oyster firmly against the head-plate. The head-plate has a breadth of 5.3 cm and a height of 7.0 cm. The movable jaw is 5.5 cm broad and 8.5 cm high. The shaft is 11.5 cm long and its diameter is slightly less than 1 cm. The components are individually made to size and shape and are heat treated to sufficient hardness. They are then assembled to form the oyster stand.

Shell speculum: The shell speculum is used to keep the oyster open for the duration of the operation. The instrument is 14.5 cm long and consists of two components, which are made by forging from round bar stock to proper size and shape. Each component has a long straight portion and an arc. The two arms are fitted together by a male-female joint at about 5 cm from the tip. The top of the straight portion is flat and rectangular with rounded corners. The spring between the two arcs keeps the instrument in a closed position normally. A metal collar, which is provided around the straight arms, helps regulate the distance between the flat ends as desired. A maximum opening of 1.5 cm is obtained between the flat ends with the collar pushed to the bottom. This is about the distance between the two valves of the operable size oyster when the adductor muscle is in a fully relaxed condition under narcotisation. When the oyster partially opens its shells, the flat end of the speculum is inserted between the two valves. By gently closing the two arcs, the flat ends open and along with them also the shell valves. When the desired gap is obtained, the collar is slipped down to maintain the gap. The maximum possible opening between the shell valves differs from oyster to oyster.

Retractor: It is a slender, flat rod 15 cm in length, provided with a sharp bent hook at the tapered end. The retractor is used to hold the foot of the oyster in a stretched position during the operation.

Lancet-cum-graft lifting needles: There are three such needles. Each needle consists of an elongated spindle-shaped aluminum handle in the middle (6.5 cm long), with a lancet and a graft lifter, each 5.5 cm long, at the two ends. The lancet is a thin (2 mm) stainless steel tapered shank with its tip slightly curved and flattened to form an elliptical blade. The edge of the blade is rendered smooth and sharp. The graft lifter is similar to the lancet, but the tip is provided with a sharp, pointed spur. The lancet is used to make a sharp incision at the base of the oyster foot and to cut a channel through the tissues of the gonad up to the site chosen for nucleus implantation. The spurred tip of the needle is used to pick out the small graft tissue from the wooden block and to insert it into the site of implantation through the channel. The sizes of the cutting blade of the lancet and the spur are a graded series according to the size of the graft tissue to be lifted. The lancets and graft lifters are made to the desired shape and size by hand forging and finished by filing and grinding with abrasive wheels. They are polished to the required extent and fitted to the handle.

Nucleus-lifting needles: These are similar in construction to the needles described above, but are provided with hemispherical cups at both ends of the shanks. There are three such needles, each with two cups at the ends. The cups are of different dimensions to enable lifting of nuclei (spherical shell beads) of 2–8 mm diameter range. The cup shoe is initially drawn by hand forging and finished to dimensions by pressing with iron balls of proper size in the cold condition. Then the hemispherical cup is cut to the required size of slightly less than the diameter of the sphere and

imparted a vacuum finish. The cup is moistened by dipping in seawater and made to touch the dry surface of the nucleus which immediately adheres to it. The cup end is inserted into the channel through the incision cut on the body of the oyster and the nucleus is placed in contact with the tissue graft. While withdrawing the needle, the nucleus is made to drop from the cup by a slight turn of the needle.

Procedures:

Spherical shell beads are used as nuclei to produce round pearls. These beads are prepared out of thick shells of other molluscs, usually freshwater mussels. These shells are imported into Japan from USA, where the freshwater mussels, popularly called pig-toe shell (Tritogonia), three-ridge shell (Pleurobema) and washboard shell (Megalonais), themselves known to produce pearls, occur in the tributaries of the Tennessee River. Alternatively, locally available thick molluscan shells which have a composition akin to pearl oyster, as for example the shell of the chank Xancus pyrum, can be used after studying the specific gravity of the material and other characteristics. Molluscan shell material is preferred due to phylogenic affinity, chemical composition, binding strength and heat resistance properties which are similar to those of the nacre. The shells are processed into spherical beads of different diameters, generally 2–7 mm for Pinctada fucata, through cutting, grinding, shaping and polishing using appropriate machines and tools. Dimensional accuracy, smooth finish and high polish are important factors. The beads should be cleaned and dried before use.

The factors to be considered in the selection of oysters are their weight, reproductive stage of development and overall health. A weight of 25 g or more is the ideal size for implantation, while 20 g oysters can be considered for implantation of smaller size nuclei, i.e. 2–3 mm in diameter. Fully matured oysters are not suitable, since during surgery the gametes tend to flow out and block the visibility of the implantation site so that proper orientation of the mantle piece and nucleus cannot be ensured. Therefore, oysters in the immediate post-spawning recovery phase or those in the early phase of gametogenesis should only be selected. This factor in turn decides the annual surgery period. In addition, the oyster should not suffer from polychaete blisters, sponge borings and trematode infection. The selected oysters should be cleaned and all the fouling organisms carefully removed.

The donor oysters do not have to be subjected to any conditioning process, which the recipient oysters have to undergo. Small pieces of the pallial mantle taken from the donor oysters are used as grafts for implantation.

The donor oyster is cut open as follows:

Hold the oyster dorsal side down and the posterior end facing the technician.

Insert the curved end of oyster knife between the two valves at the posterior side.

Push the knife straight through the oyster until the knife tip reaches the anterior end.

Press the knife straight downwards to cut through the adductor muscle.

Separate the two valves by tearing the hinge, without disturbing the two mantle lobes. If disturbed, the lobes will shrink and cannot be used.

The steps involved in the removal of the mantle (marginal and pallial region) are given below:

Deal with one valve, with the adhering body tissue, at a time.

Expose the mantle lobes by gently brushing aside the gills with the tip of spatula. Care should be taken for the mantle not to shrink.

With the aid of the knife, starting from the posterior margin, cut the mantle tracing a curve up to the anterior margin.

Using the forceps, lift the mantle gently and place the tissue on a soft, clean, moist wooden block without changing the side. At this stage the inner epithelium of the mantle is facing the technician.

Further steps in the preparation of graft tissues are as follows:

Gently stretch the tissue end to end.

With a wet sponge, gently wipe out all the mucus and dirt.

Use the graft knife to cut away the marginal mantle (this mantle is characterized by numerous folds and it is highly pigmented).

In the same manner cut away the inner muscular portion of the mantle on the opposite side.

Again wipe the mucus and dirt with a wet sponge.

Holding one end, lift the mantle ribbon, reverse the side (top to bottom) and place it on the block. Now the outer epithelium is facing the technician.

Wipe the mucus and dirt softly without causing damage to the outer epithelial layer.

Trim the margins on either side until a mantle ribbon of about 3 mm width is obtained (Fig 6 B and C).

Remove all the dirt and mucus from the wooden block. If necessary, transfer the mantle ribbon to a new block without changing sides.

Use the graft knife to cut the ribbon into small pieces (2–3 mm). The size of each piece has to be in proportion to the size of the nucleus (Fig 6 D).

With the use of a soft brush smear the mantle pieces with a highly diluted solution of water-soluble eosin.

Keep the tissues moist until they are used within about 30 minutes.

Precautions

Care should be taken to ensure that the knife does not injure the palm of the technician while inserting it between the valves of the oyster.

Use only clean, sterilised, filtered seawater throughout the operation.

All instruments must be washed and sun dried before their use.

Sponges must be clean and moist. Different sections of the sponges must be used for each wiping operation.

Wooden blocks must be clean, smooth and moist all the time.

Shrunken mantles should not be used due to difficulty in handling them.

Conditioning of the recipient

Natural conditioning is ideal and inexpensive, however it can be practised only in regions where there is stratification of seawater temperature, as well as sharp difference in food availability. This method works well in the sea conditions in Japan. Using the thermal differences, the oysters are spawned in the upper water layers which have a relatively high temperature. With the loss of the stored energy, due to spawning, the weakened oysters are further subjected to starvation by placing them at depths where phytoplankton production is low, in order to reduce their metabolic rate. Such conditioned oysters can be readily used in surgery.

Where such techniques do not work, such as in Indian waters, chemical conditioning is resorted to. Menthol crystals are sprinkled over the seawater in the tanks in which the oysters are placed. In about 60–90 minutes, the oysters become narcotised and relax their adductor muscles and open the valves. The time of response varies with the water temperature, however once narcotised the oysters become almost non-responsive to touch. The conditioned oysters are usually operated within the next 10 to 15 minutes as prolonged exposure causes swelling of tissues, copious

secretion of mucus and mortality. A duration of about 30–40 minutes after response is the safe limit, and therefore the pearl oysters should be treated in batches.

The number of nuclei to be implanted in one oyster is usually decided before the operation. Single and double implantations are common while multiple implantations are usually carried out when large numbers of small pearls of about 2–3 mm are required. Large diameter nuclei, in the range of 6–7 mm, are generally used in single implantation, one nucleus in each oyster. Nuclei with diameters ranging from 4–6 mm are used for double implantation, a large and a small one in each oyster. Nuclei with diameters of 2–3 mm are generally used in multiple implantations, five or more nuclei in one oyster.

The best site for nucleus implantation is the gonad, particularly in its ventral portion. Single implantation is always done at this site. In double implantation, the above site is used for the larger nucleus while a site in the dorsal region of the gonad, close to the hepato-pancreas, is used for the smaller nucleus.

The steps involved in pearl oyster surgery are as follows:

Insert the end of the speculum through the posteroventral corner of the oyster and open it by sliding backward the gap-regulator ring. Attention should be paid not to open the oyster too much as the adductor muscle may snap and kill the oyster.

Mount the oyster with the speculum on the clamp. The oyster should be placed correctly between the two plates of the clamp so that it does not slip. The speculum is now towards the left-hand side of the technician.

Hook the tip of the foot with the needle with the left hand and gently pull it so that the base of foot is slightly elevated. Hold the needle in position until the operation is completed.

With the oval knife end of the incision-cum-grafting needle in the right hand, make a sharp incision at the base of the foot. Through this opening, passing the needle below the outer skin, steadily and gently cut a passage through the gonad connective tissue up to the site of implantation. Gently withdraw the needle.

Pick a piece of graft tissue, already on the block, with the tip of the needle (same needle as above but reversed) and gently insert it through the passage cut in the gonad. On reaching the site, gently deflect the needle and allow the graft tissue to drop. Withdraw the needle. Now the outer epithelium of the graft tissue is facing the passage (Plate VIII B).

Lift a nucleus with the moistened cup end of the appropriate nucleus-implanting needle and gently insert the nucleus through the gonad (Plate VIII C and D). On reaching the site, deflect the needle gently so that the nucleus drops. At this stage the nucleus must be in contact with the outer epithelium of the mantle tissue which was grafted into the gonad by the preceding step. Withdraw the needle gently through the passage.

Smoothen the incision with the cup end and let the two margins of the incision come in contact. The nucleus implantation operation is now over.

Remove the oyster from the clamp, withdraw the speculum by slipping the gap-regulator ring forwards and place the oyster in clean seawater.

Precautions

Before and after use, wash the instruments in clean seawater.

Adjust the pressure on the foot in a way that the foot does not get torn while pulling it with the needle hook.

The incision should be a sharp cut and of the required length for the size of nucleus to be inserted. If the incision is too large the nucleus may slip out. If there is too much tear of tissues, do not proceed. Place the oyster back in fresh seawater and return to the farm for future use.

While cutting the passage through the gonad, if there is copious flow of gametes, do not proceed but return the oyster to the farm.

Do not cause damage to the vital organs such as stomach, intestine and heart during the surgery.
The orientation of graft tissue (outer epithelium) and nucleus should be correct.
Skill and patience are the key factors for a successful operation.

Post operation.

Freshly operated oysters should be reared undisturbed for a few days. If kept in the laboratory, they should be placed in plastic troughs or FRP tanks, where seawater is allowed to flow gently. If no flow-through system is available, the seawater has to be changed frequently to overcome the narcotizing effect of menthol. When normalcy is resumed, the oysters slowly re-open their valves and commence their pumping and filtering activity. If the sea is not calm, it is desirable to rear the operated oysters under laboratory conditions till the wound heals completely. The normal duration of wound healing is only a day or two. However, if the surgery is rough or the incision is large, the nucleus could slip out of the oyster, if cultured in rough waters.

In Japan, newly operated oysters are hung in deep and calm waters for a period of 2–3 weeks, by which time they recuperate fully. Afterwards they are hung as in normal culture practices. However, in areas where the inshore waters are not calm, as in India, it is always advisable to keep the operated oysters for 3–4 days in the laboratory under observation and then transfer to the farm. If the oysters are suspended in rough sea immediately after the operation, they will be subjected to undue stress, which may lead to the dislodging of the nuclei.

Some Japanese pearl culturists examine the pearl oysters individually after recuperation by fluoroscopy, in order to check the condition of the inserted nucleus. Only those with the nucleus in the proper position are further cultured for pearl production, while the rejected ones will be retained as mother oyster for future use.

The quality of the pearl to be formed is influenced by several hydro-biological factors, such as primary production, temperature, current, trace metals content, etc. Coastal waters deeper than 5 m are usually favourable for the formation of high quality pearls. However, the culture site and depth at which the hanging culture structures should be fixed must be carefully chosen to have the most favourable conditions for the culture of the pearl oysters.

During the post-operation rearing period, the oyster density in the culture cages and culture grounds should be kept at a minimum. Over-crowding may cause adverse effects such as production of low quality pearls, slow formation of the nacre layer, shell damage and physical stress, as well as oyster mortality from diseases and parasites.

The oysters must be suspended in areas of high phytoplankton production and also at greater depths than the mother oysters. Settlement of undesirable organisms and silt on the oysters is responsible for the formation of poor quality pearls, slow formation of the pearl layer and oyster mortality. Hence the oysters should be monitored periodically and fouling organisms thoroughly eliminated. In Japan, when the seawater temperature drops below 10 °C during winter, the rafts are towed to warmer water bodies to allow the pearl oysters to over-winter.

The length of the culture period following the operation phase depends on the size of the nuclei inserted and the desired size of the pearls to be obtained. The Culture period ranges between 3–24 months for 2–7 mm diameter nuclei under tropical conditions. Periodic sampling of each oyster batch will give the basis for deciding on when to harvest. Pearls with a thin nacreous layer usually will not have good lustre and iridescence, and therefore command a lower market price.

Much later, the harvesting.

Harvesting of the cultured pearls is usually carried out manually. However, the process can be automated with the use of simple machines. In the case of manual extraction the pearls are collected by initially separating the two shell valves, by cutting the adductor muscle, making an incision on the gonad and squeezing the pearl out. The machines used for pearl extraction usually work by dissolving the oyster soft body parts with the use of chemicals while the pearls remain as they are and become easily extractable. In case the oysters need to be re-used for a second time, the pearls are carefully removed by opening the pearl-sac through the gonad taking care not to damage nor stress the oyster. The oysters are then returned to the culture site for recovery, and after a certain length of time they can be operated for a second time to produce additional pearls. In Japan, harvesting is done during periods of low temperature and pH as the pearls tend to be of higher quality due to a thick and compact outer nacreous layer.

Finally, the harvested pearls are washed in distilled water, polished with refined salt and sorted for sale according to size, colour, shape, lustre and other external characteristics.

Nuclei ejection does not commonly occur, particularly in the case of large ones. However, this miss-happening can be kept to the minimum by improved surgical methods. Discharged nuclei are usually thrown away. However, in some cases they are retained for re-implantation as no nacre has been deposited over them, probably due to the non-formation of the pearl-sac. Defects in surgery and incorrect orientation of the nucleus and graft are two of the reasons for this defect. In cases of non-formation of pearls, the nucleus may either remain as it is or become eroded.

As in the case of natural pearls, the production of cultured pearls is also a result of a biological process within the pearl oyster itself. Therefore, the quality and the rate of cultured pearl production are only partly controlled by the activities of the pearl culturists. The production rate can be improved by adopting appropriate technology and care during surgery and subsequent culture. 'Gross production' usually refers to the number of cultured pearls produced by oysters which have survived the implementation of the shell bead. In India, the highest recorded production rate achieved in single implantation was about 65%, while in multiple implantation, a rate up to 180% has been obtained. This rate can definitely be improved by professional technicians with considerable knowledge and practical experience.

The gross production of pearls includes all kinds of pearls, from the finest quality to trash. Usually a small percentage of the pearls produced have an outstanding colouration and perfectly round shape, while a large proportion are inferior and some totally valueless as gems. This is a common feature in all pearl culture centres around the world. Generally the success of a pearl culture industry depends greatly on a high production of good quality pearls as a percentage of the total numbers produced.

Shirai (1970) has categorised the cultured pearls as follows:

Class A: Features: flawless, one flaw, small flaws, small stain marks, pink, silver or light cream in colouration. These pearls are further classified into:

A-1: Top pearls-perfectly round, pink, flawless and lustrous. This class may also include pearls with small blemishes of the size of a pin point.

A-2: First class pearls - with slightly larger pits and protuberances. When treated these pearls become indistinguishable from the pearls categorized as A-1.

Class B: Features: fairly large flaws, stain marks, creamy in colouration, and irregularities in the shape.

Class C: Features: wild shaped, badly coated, heavily marked, clayey lumps, half good and half bad. These pearls are usually referred to as 'trash pearls'.

Generally, in a commercial pearl culture farm the combination of class A and class B pearls should account for at least 60 % of the gross production of cultured pearls for it to run economically. The remaining 40 % of class C pearls are usually rejected. However, their nuclei can be often salvaged and reprocessed.

Improving production – notes from the FAO

Quality commands a premium price in pearls. The success of the pearl culture industry depends on the high rate of production of quality pearls. Therefore, considerable attention is paid to this aspect. The value of a pearl is decided by its quality, size, shape, colour and lustre. Exceptional pearls command special premium price.

Being a product of biological origin, individual variations are bound to occur in each and every pearl. The secretion of the mantle or the pearl-sac, which leads to the formation of the pearl, may be organic or inorganic in origin, or a combination of both, with unpredictable and subtle variations in structure and composition. The final product may range from the finest to the trash due to such variations.

Even under the highest possible human control, the quality of cultured pearls cannot be controlled absolutely, but can be considerably improved through appropriate care in surgery and during farming. Only the size and shape of the cultured pearls are under the control of the pearl culturist. However, the colour and lustre, which depend on the secretion of the pearlsac, can also be improved to some extent by proper understanding of individual biological and physiological factors as well as the environmental conditions of the culture farms, which influence the formation of pearls.

To achieve a high rate of production of quality pearls, the following factors are required to be taken care of:

Oyster selection

Large oysters, in terms of size and weight should be selected. They must be free from a heavy fouling load and blisters caused by sponges and polychaetes. The oysters should be healthy as can be judged from the colour of the visceral mass and gills.

Narcotization of oyster

The amount of menthol required to narcotize, and the duration of narcotization should be carefully adjusted depending on the volume and weight of the oysters.

Graft tissue preparation

The graft tissue is one of the most critical factors in controlling the rate of pearl production. The donor oyster should be of the desirable size with a well developed and healthy mantle. Extreme care should be taken in selecting, stretching, cleaning, trimming and cutting of the donor mantle tissue. Good water quality and correct level of the chemical agents should be used in maintaining the tissue pieces.

Implantation

The nucleus implantation is one of the most important factors in cultured pearl production. Its success greatly depends on the selection of the correct site and skill of the technician. The positioning and orientation of graft tissue in contact with nucleus is also critical and should be carried out with great skill and patience. Multiple nucleus implantation requires still greater care and patience.

Oyster convalescence

Oysters can be made to recover from the effect of narcotization through periodic changes of water or gentle flow-through. Sufficient time must be allowed for the incision wound to heal before taking the oysters to the sea for further farming.

Tool maintenance

The tools must be sharp, rust-free and should have been either sterilized or suitably cleaned and sun-dried.

The FAO also suggests considering the environment:

Temperature controls the metabolic rate of the molluscs. Higher temperature leads to faster growth in oysters and higher rate of nacre deposition. But this affects the quality of pearls. Thinner laminar nacreous layers, which result from low temperature and pH, are desirable at least in the later phase of the culture period, since the thinner mineral laminae in the upper layers of the pearl give a better lustre to the pearls.

The physiological state of the pearl oyster and the condition of the culture ground have bearing on oyster growth and the size and colour of pearl. This depends principally on differences in chemical composition of the seawater, as well as the kind and amount of plankton in the area where the pearl oysters are reared. The chief source of conchiolin are the nitrogenous substances of the plankton, which influences the colour of pearls.

Minerals and trace elements in the seawater are important, as these also influence the colour of pearls. It has been found that the golden and cream coloured pearls contain more copper and silver, while skin coloured and pink pearls contain more sodium and zinc. The golden coloured pearls have been found to contain more metallic elements than green pearls. The pearl colour varies according to the amount of porphyrins and metalloporphyrins present in them. Iron-bound peptide in the nacre favours the formation of yellow pearls. The organic substances deposited at the beginning of the pearl formation also would influence the colour. Good quality blue pearls are of this origin.

Pearl oysters are typically raised in seawater, while pearl mussels are raised in freshwaters. Natural freshwater pearls form in various species of freshwater mussels of the family Unionidae, which live in lakes, rivers, ponds and other bodies of fresh water. These freshwater pearl mussels occur not only in hotter climates, but also in colder more temperate areas such as Scotland.

CHAPTER THIRTY:
ON CO-OPERATIVE CORPORATIONS AND COMMONWEALTHS

Introduction to cooperative corporations and commonwealths: they naturally form as a human sociological phenomenon, are governed by the natural laws of society and by artificial laws; only those which are formed and governed by the consent of the members will function. There are five organs to the cooperative: that which makes the rules that govern members, that which enforces the rules, that which allows members to approve the rules, and those which advise the others upon spiritual and temporal affairs. The cooperative and commonwealth function as a person, and are an "artificial" person, with its own sovereignty. Some cooperatives and commonwealths are members of other cooperatives and commonwealths. There are 5 kinds of cooperatives: casual, domestic, simple, complex and commonwealth.

The lesson gained from a thorough study of agriculture is the importance of cooperation. Together, we can do more than any of us could do alone. The lesson is a simple one: what is the strength of one ant, except that she has many sisters to help her? What is the strength of one beaver, except that it has brothers, sisters, parents, nephews, nieces and children to help? What is the strength of a single family, but that they have strong, healthy, happy neighbors who, by the sacred bonds of incorporation, have gathered to form a moderated government?

When the wind blows strong against a forest, some trees bear the weight of the fury more than others to save their kin, and when a crisis would destroy a every family in a neighborhood, if that neighborhood is well governed, no one family bears the burden alone. All suffer the tax a little so that, as a whole, the community is stronger: the complete loss of any one family in a neighborhood to a catastrophe is more damaging than the slight weakening of every member of that community, even if both are equally expensive because in the first a permanent loss of assets occurs, and in the second, only a temporary loss. It is better to grab hold of a heavy weight with all your fingers and disperse the weight between them: suffer a tired hand that will quickly recover rather than put all the weight upon one or two fingers and break your bones.

But besides preventing damage and avoiding disaster, there are advantages to working together. When divided among many families, expensive investments that benefit all families equally are more affordable. A rising tide floats all boats, and to build the harbor would bankrupt one family but be an inconsiderably small expense if divided among several or hundreds of families. Thus, any farm can hope, through the cooperation of its neighbors, to retain a ready source of water, obtain electricity for power, or have good roads to the nearest town's market. No farm need fear fire or bandits, no farmer need fear injury because of the cooperative hospital.

There are five ways people cooperate.

The most basic cooperation typically occurs between people in the same way that each farmer cooperates with the wildlife in their fields: casually.

If casual cooperation persists for a while, each cooperating partner will become familiar with each other and establish ad hoc agreements, exchanging this service for that service, or goods for

services. If this happens regularly, the bonds that bind these friends imitates a filial bond and a domestic (or friendly) cooperative results. Domestic cooperatives naturally result from birth relation, as well.

If the friends work together in complex ways, or if there are many friends, they will seek to establish a corporate business entity by which their relationships may be more fairly governed and agreements recognized. Each member helps enforce the agreements of the others, and by this means the friends remain friends, and have no recourse to the local judicial authority to moderate disagreements. If this corporate entity is for a single project or short-term projects, we call it a simple corporate cooperative because the founding members will remain in constituency for the duration of the cooperative.

If this corporate entity is designed for ongoing or long-term projects, we call it a complex corporate cooperative because it is inevitable that the original founding members will be joined by others or drop out of the cooperative before its conclusion. Thus, it is a cooperative friendship of strangers.

You may observe that as cooperatives become increasingly complex, the interests members hold in each other and their mutual resources increase and become more and more permanent. If the complex cooperative evolves to the point where the shares members own in it are permanent, if all property and persons are mutually owned, it has become a commonwealth for all wealth is held in common in perpetuity.

Sir Thomas Hobbes was the first to study the process by which sovereign governing bodies are incorporated. When he examined how families of people naturally organize and how friendships between people behave, he was able to describe the natural laws that govern those bonds and in doing so came to understand their influence on corporate entities. In describing the commonwealth as nothing more than a very great family, he also describes the cooperative corporation as a very great family.

Sometimes a family or friendship is governed by a strong man or woman, sometimes by many brothers and sisters. But in corporate entities, the family is governed by written rules – artificial laws. The system by which these laws are made and the system by which the laws are enforced and enacted constitute two essential "branches" of power, but it is the third "branch" of power – the system by which laws are approved by those who they would govern – that allows the family to function. The addition of systems for guiding and advising those branches of power in both spiritual and temporal affairs improves their efficiency.

Hobbes described these five systems as kinds of organs for a body of an artificial man he named "Leviathan." Leviathan, though nothing more than a large family, behaves as a single entity and has its own memory, its own personality, its own history. It is a sovereign entity, able to undertake treaties and contracts with men and women and other Leviathans. It outlives any of its member persons, it is immortal. Though its leadership will doubtlessly change during its infinite life, it is bound by its constitution of artificial laws to limit the caprices of its leadership, transforming individual leaders from directors into administrators. Thus, each administration of Leviathan resembles the last in most respects. The essential third branch of approval requires this, for the consensus of those numerous individuals will change less over time than the beliefs of any one of their leaders. Says Hobbes,

NATURE (the Art whereby God hath made and governes the World) is by the Art of man, as in many other things, so in this also imitated, that it can make an Artificial Animal. For seeing life is but a motion of Limbs, the

beginning whereof is in some principall part within; why may we not say, that all Automata (Engines that move themselves by springs and wheeles as doth a watch) have an artificiall life? For what is the Heart, but a Spring; and the Nerves, but so many Strings; and the Joynts, but so many Wheeles, giving motion to the whole Body, such as was intended by the Artificer? Art goes yet further, imitating that Rationall and most excellent worke of Nature, Man. For by Art is created that great Leviathan called a Common-wealth, or State, (in latine Civitas) which is but an Artificiall Man; though of greater stature and strength than the Naturall, for whose protection and defence it was intended; and in which, the Soveraignty is an Artificiall Saul, as giving life and motion to the whole body; The Magistrates, and other Officers of Judicature and Execution, artificiall Joynts; Reward and Punishment (by which fastned to the seate of the Soveraignty, every joynt and member is moved to performe his duty) are the Nerves, that do the same in the Body Naturall; The Wealth and Riches of all the particular members, are the Strength; Salus Populi (the peoples safety) its Businesse; Counsellors, by whom all things needfull for it to know, are suggested unto it, are the Memory; Equity and Lawes, an artificiall Reason and JPill; Concord, Health; Sedition, Sicknesse; and Civill war, Death. Lastly, the Pacts and Covenants, by whiqh the parts of this Body Politique were at first made, set together, and united, resemble that Fiat, or the Let us make man, pronounced by God in the Creation.

To describe the Nature of this Artificiall man, I will consider

First, the Matter thereof, and the Artificer; both which is Man.

Secondly, How, and by what Covenants it is made; what are the Rights and just Power or Authority of a Soveraigne; and what it is that preserveth and dissolveth it.

Thirdly, what is a Christian Common-wealth.

Lastly, what is the Kingdome of Darkness.

Concerning the first, there is a saying much usurped of late, That Wisedome is acquired, not by reading of Books, but of Men. Consequently whereunto, those persons, that for the most part can give no other proof of being wise, take great delight to shew what they think they have read in men, by uncharitable censures of one another behind their backs. But there is another saying not of late understood, by which they might learn truly to read one another, if they would take the pains; and that is, Nosce teipsum, Read thy self: which was not meant, as it is now used, to countenance, either the barbarous state of men in power, towards their inferiors; or to encourage men of low degree, to a sawcie behaviour towards their betters; But to teach us, that for the similitude of the thoughts, and Passions of one man, to the thoughts, and Passions of another, whosoever looketh into himself, and considereth what he doth, when he does think, opine, reason, hope,feare, &c, and upon what grounds; he shall thereby read and know, what are the thoughts, and Passions of all other men, upon the like occasions. I say the similitude of Passions, which are the same in all men, desire, feare, hope, &c; not the similitude of the objects of the Passions, which are the things desired, feared, hoped, &c: for these the constitution individuall, and particular education do so vary, and they are so easie to be kept from our knowledge, that the characters of mans heart, blotted and confounded as they are, with dissembling, lying, counterfeiting, and erroneous doctrines, are legible onely to him that searcheth hearts. And though by mens actions wee do discover their designe sometimes; yet to do it without comparing them with our own, and distinguishing all circumstances, by which the case may come to be altered, is to decypher without a key, and be for the most part deceived, by too much trust, or by too much diffidence; as he that reads, is himself a good or evil man.

But let one man read another by his actions never so perfectly, it serves him onely with his acquaintance, which are but few. He that is to govern a whole Nation, must read in himself, not this, or that particular man; but Man-kind: which though it be hard to do, harder than to learn any Language, or Science; yet, when I shall have set down my own reading orderly, and perspicuously, the pains left another, will be onely to consider, if he also find not the same in himself. For this kind of Doctrine, admitteth no other Demonstration

Leviathan is an artificial person, and resembles in most respects the individual persons of which it is composed. By our nature, humans are social creatures. Just as horses will organize themselves socially into herds, people organize themselves into cooperatives and commonwealths. The necessity of having written contracts is too great to ignore, and when written contracts are made, they must be enforced, and when they must be enforced, there must be checks upon them so that they are written with the consent of those whom they govern. It is a hop, skip and a jump from a buyer's agreement ("I will buy that from you at this price at the time agreed upon") to a buy-sell agreement ("Let us trade these things and services at this rate at that time") to a cooperative agreement ("Let us be friends, let us be like family: let us always work together by these terms to accomplish these projects for this purpose"). It is a hop, skip and a jump from cooperation to commonwealth ("Since we are like family, let us combine our resources for our mutual benefit, we shall belong to each other, defend each other, help each other grow, etc."). The fundamental relationship of husbands and wives (whether they are plural or singular) is imitated by their children and their brothers and sisters and, in the case of marriage, each becomes the property of the other. By mutually holding each other as property, husbands and wives have a special interest in each other; they are partners.

And what is cooperation if not a partnership? Cooperation is the making of family and friends, the keeping of family and friends. Depending on the charter of the cooperation, there will be more or less mutual ownership of property and constituents, but in commonwealths, all property and constituents are mutually owned. A commonwealth cannot be dissolved or left by any member, only by the unanimous consent of the members. An exception is when the commonwealth is itself subject to another commonwealth, or is subject to a person. Then, being the property of that person or commonwealth, it can be dissolved, or its members dismembered.

In cooperatives, there is freedom of entry and exit, so long as the interest owned in the cooperative is returned to the cooperative upon exit: these "shares" are sold and bought like property.

The five organs of a cooperative or commonwealth must be present in any organizational structure; officers of cooperative or commonwealth must be subject to the constitutional bylaws of their incorporation

The organizational structure of a cooperative must include the five elements essential to any corporate entity. The officers of the cooperative or commonwealth must be subject to the constitutional bylaws of their incorporation.

Typically, it has been found that the bylaws and direction of a cooperative or commonwealth is best done through a small body of equals: the debate and discussion that this structure allows better decisions to be made. However, with this structure, the body is encouraged to act as its own spiritual and temporal advisors: in the debate, every member has an opinion. Thus, it is much better to have a single officer undertake the writing of the bylaws and the direction of the projects.

Typically, the bylaws and directions are enforced and enacted by a single administrating officer, but it is much better to divide such work among many specialists who can also act as advisors to their director. But do not neglect to give the director impartial advisors if you wish them to obtain unbiased advice! Administrators tend to hunger for resources and authority.

Typically, the bylaws and direction are approved by the shareholders, as they should be. It is typical to indirectly approve directions and bylaws by either opting to continue the terms of the directing officer or officers, or by terminating their appointment to that office. This allows speedier action by the director, as the time it takes for the shareholders to debate and approve or disapprove is lengthy. A compromise that allows more shareholder input is the election of representatives from the shareholders into a board that is better able to represent their interests. The effectiveness of a board is questionable, as it often more serves to circumvent the authority of the shareholders rather than extend it. However, for very cooperatives and commonwealths where day-to-day directions remain constant over a long term, this is a very appropriate course of action: there is no need to consult the shareholders every time a direction is made if the direction is largely similar to the last direction. Independent consultants for both temporal and spiritual concerns of the directors, the administrators and the shareholders should not be neglected: a cooperative or commonwealth should retain both ethical and economical perspectives in all actions if it is to meet with long-term success.

Utility, commercial, residential and labor cooperatives, definition and purpose

There are many kinds of cooperatives and commonwealths, but they may be grouped by the services they provide to their shareholders.

Utility cooperatives and commonwealths provide resources, whether those resources include electricity, water (for irrigation or drinking), trash disposal, fuel, or other necessities. In this kind of cooperative are also found the libraries, universities, colleges, schools, research and development facilities and other educational and scientific utilities so necessary to the processes and progresses of civilization.

Commercial cooperatives provide advantages to buyers and sellers who wish to hold mutual interest in each other: the evolution from a buy/sell contract from a barter agreement into a long-standing alliance will likely eventually develop into a commercial cooperative. Thus, a bottle manufacturer, a beer brewer, a barley farmer and a hops farmer might form a commercial cooperative that establishes a relationship between all four members: the hops, the barley, the beer and the bottles all become mutual property, and the profits of the sale of the beer or any surplus bottles, barley or hops benefits all four members equally. They undertake to share resources for their mutual gain, and distribute any losses among themselves.

Residential cooperatives provide housing to their shareholders: together, a number of people may own an apartment complex, campgrounds, or other locations on which they obtain their residence. Their share typically includes a legal description of land or real estate, and when they sell or buy shares, they are effectively buying or selling real estate or land. Yet the cooperative retains ownership of the land, and establishes a system by which all residences may live together peaceably, sometimes even providing internal courts, law and by law enforcement, and essential services. The shareholders share the taxes of the land and any damage to the land or building.

Labor cooperatives provide regulatory services to their shareholders so that at any time there are not too many laborers providing service to the market, controlling the price of their labor. They cooperatively bargain for wages, and typically share equally all labor hours an employer will provide. These labor cooperatives are also called "unions." Typically, they also provide retirement benefits to their shareholders, disability services to their shareholders and help make the workplaces their shareholders find employment in safer.

Beginning co-operatives and commonwealths

Benjamin Franklin was by far most responsible for the organization of our American commonwealth. Early in his life, he organized cooperatives and grew them into greater and more profound organizations. He invented the public library by inviting all his friends to contribute their books into a common-wealth, a common ownership of resources and established bylaws by which those common resources were to be protected, preserved and increased: all members were obligated to contribute so many books and/or so much money per year to the cooperative, and a building in which those common resources could be stored. The building was then also used as a kind of institution of learning, where books would be read and discussed in groups, where reports and investigations were made and commissioned.

He also invented the modern public fire protection and civil defense cooperatives. By requiring all citizens to contribute money and/or services to provide the equipment and personnel required for fire extinguishing equipment and civil defense, the cost was not burdensome to any citizen and everyone benefited: it was in the interests of the wealthy to protect the houses of the poor from fire (or else the fire would certainly consume the entire town or destroy enough property to inhibit economic development), and certainly in everyone's interest that the town was protected from hostile neighbors and criminals.

Through the formation of these and other cooperatives, his people learned that by working together more was possible at less cost than working alone and these small experiments prepared them to take a leading role in that great undertaking, the foundation of the United States of America. The people were prepared to self-govern, and indeed were already providing all their own services when their King sought to tax them to provide those services too. Such services from the King were neither wanted nor needed: they provided for themselves.

The first step to organizing cooperatives or commonwealths is to establish a committee (even if it is a committee of one) to propose bylaws. The bylaws must then be subjected to the approval of the shareholders. Then, the shareholders, as directed by their bylaws, enact those bylaws and choose advisors for their administrators and directors. The administrators and directors then procure those resources that they are asked to govern: these are paid for by the sales of shares to the shareholders, who either pay for their shares by contributions of money, goods or services, or the contribution of those resources the cooperative governs: to join Franklin's public library, you had to purchase a share (library card) or contribute a certain number of books that the library required, as directed by its governing board. The actual acquisition and addition of shareholders was undertaken by the administrating librarians.

The directors must determine and constantly review how many shareholders may be allowed into the cooperative or commonwealth (even if it is unlimited), and how new members are selected (what qualifies them to membership? Is it simply the purchase of shares, or do they need to meet other qualifications of mental or physical aptitude?). The directors, shareholders and administrators will then naturally increase their authority and eventually govern all the resources of their shareholders, forming a commonwealth.

In most States of America, cooperatives are governed as corporations, and the process of registering a corporation applies to the registration of cooperatives. You should consult a lawyer, your State's constitution, Secretary of State or Governor to learn how to establish a cooperative, and how or whether you can grow that cooperative into a municipal corporation.

Many small farms can have every advantage of a large one; inequality within the cooperative or commonwealth, and the reason why the weak and strong should cooperate for mutual benefit.

A conclusion

Columella correctly explains that it is best to admire large farms and manage a small farm well, but through cooperation, many small farms may be both well managed and coordinated to take full advantage of the admirable situations enjoyed by large farms. The advantages of a large farm's economy of scale and the advantages of a small farm's well administered resources can be combined through cooperatives. If many small ants, whose beautiful farms are the adoration of agriculturalists everywhere, can work together to move mountains, what can so many small human farmers do?

Only lift your eyes from the ground a moment, friend, and you will see the stars high above you. They promise you the great inheritance of your ancestors if you will but take it.

Never will all people be equal. There will always be some that are bigger, and some that are smaller, some that are stronger and others that are weaker; there will be those that are skilled and those that are unskilled. Yet the weak should never have to fear the strong, especially not when there is law that governs all citizens equally! Weak or strong, the rule of justice favors no one and the rights of the weak are as valuable as the rights of the strong.

It has never been true that from those who are bigger or have more, more is required: when have the smaller or those who have less ever had less required of them? The strong rebel at the idea of more being required of them, as they ought to. There is enough work, enough tax for everyone to pay. Those with more have as many rights as those with less because the strong and the weak are both required to do the very best they can. The same requirement stands for both weak and strong.

Yet the strong are more able than the weak and thus nature encourages the strong to undertake the work their lesser neighbors cannot. It does no good to defend your house from fire as your town burns, nor to provide security for your house alone while criminals pillage the homes of your neighbors: as strong as you are, you will eventually weaken, and you will want friends on that day, even if they are weaker than yourself. Do you not see those who are weak about you and remember the days when they and their families were strong, and consider that one day you will be as they are? Misfortune happens to the strong and weak alike, death happens to the strong and weak alike, weakness happens to everyone who grows strong. We all suffer misfortune, death, illness and injury: we are compelled to undertake those acts of honor and valor that we might while we are strong, healthy and fortunate.

Columella encourages the strongest among us to do those heroic tasks that only the strongest can do so that those who are weaker do not lapse into the slothfulness and idleness of despair: if we fail by aiming at the topmost peak and arrive only at the second summit, we enjoy enough honor when we can offer a hand up to those who are struggling behind us; in this—and all great Republics—a person risks dishonor only by not trying to be as strong as we can, and we all revel in the achievements of our great friends. Through them, we all touch greatness, and we earn honor by serving them and helping them as they do those great things only they can do. In this way, those who support become the true heroes of the day.

And it is in this quest for honor that the strong heroes among us find that, while they are not required to do more than those lesser mortals with whom they live and work, they are encouraged to do so for their own glory, for the glory of their friends who believe in them, who sing their praises by the fireside at night. This glory, this honor is, ultimately, our survival, for tales of our honor and glory will outlive us.

The lessons of labor management, the lessons of how plants and animals grow, the lessons of the cultivation of the soil lend great insight into those immortal lessons required for those who would cultivate their hearts. Sooner or later, we all crave the glory due us, the glory promised to us by the stars high above. We wish to stand tall among our ancestors and earn our great inheritance. At that moment we must confront the reality that there is no substantial difference between the hero and the lesser mortal. The hero is, after all, just a man or woman all wish to call their brother or sister, who all wish to endow with a place in heaven through prayers of goodwill.

Now, unlike in Columella's time, heroes are no longer born of godly parentage. Now, the only difference between a hero and a lesser mortal is found in their courage to do what needs done when it needs done, to take upon themselves more work than their neighbor, to improve their neighborhood not only for their own benefit, but for the benefit of all their brothers and sisters. A hero is but a man or a woman who, when given the great honor due them for their cooperation, has the courage to acknowledge the source of their happiness. The hero is the man or woman who strides to heaven upon the songs of their brothers and sisters, who earns a debt from the gods by doing those magnificent things, that godly work here on earth. By doing such wonders in the name of the gods, the hero earns the honors and glories of their brothers, sisters and gods alike. Like Hercules, by laboring for those who are weaker than themselves, the hero glorifies their God who then, rightly, bestows glory unto them – even as they are busy glorifying those who served them as they ascended to heaven. The hero bridges heaven and earth.

Jethro Tull was one such hero, and the countless other heroes we reference in this book present ample opportunity for further examples of fine leadership. To conclude our work, our service to them in updating his singular book, of bringing together the knowledge of agriculture and related sciences for the use of those farmers and other people who would most benefit from it, we will present our hopes that in doing so we have done what little needed done in bridging that mighty gap, that we achieved what we dedicated ourselves and our work to do. We dare to presume some measure of success so that we might now offer what little advice of our own as we simple farmers might give to those who would become heroes worthy of the promises of the stars:

those who would prosper
dig deeper and break ground finely

Everyone has what they need at their time of need
All that is lost is by its master soon found
Thus it matters little whether land is fertile or is sterile to a seed
If the gardener loves their work and finely breaks the ground

Nature has a good plow and we always have enough
Why then not be generous with all our stuff?
The more we give the more we can receive
This and more is granted to those who will believe

Listen friend, in life three things define our being:
Death, pain and suffering
Yet through love we are all saved
Heaven's road is by this paved
Friend, if you wish to live
Everything that is yours you must give
If you wish to not again be pained
Seek knowledge and wisdom and your liberty is gained
Do you suffer from suffering, dear friend?
Remember the rigid snaps and the supple bends.
Aggression, passion and ignorance are the way to hell
For less than these Mother Eve and Father Adam fell
A good farmer treats their crops and animals well
A good King conquers evil by wheel, sword and bell
All creatures are sentient and wide awake
Like a tree of good nuts is ready to shake
All creatures in this world have their part
All men and women gradually improve their art
Wild and domestic, all creatures are free
All creatures seek friendship with humanity
The stories of the world are told
By explaining how life and honor are bought and sold
All that is unmade by its true authors can be remade
The flame of wisdom once lit can never fade

Dig deep, drink deep, break new ground
Here's to that which was lost and is again found
Here's to the honor and freedom that never died
The lies of Darkness that Light defied!
With compassion for lost glory and upon the edge of death
Drawn upon paper as they drew their final breath
In the year 2010 were these words wrote
by Aaron Brachfeld and Mary Choate